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COMPUTER BLAST DESIGN PROGRAM EVALUATIONS FOR LARGE DIAMETER BLASTHOLE STOPES UNDERGROUND

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COMPUTER BLAST DESIGN PROGRAM EVALUATIONS FOR LARGE DIAMETER BLASTHOLE STOPES UNDERGROUND

1.0 SUMMARY

Two computer programs for the design of large diameter VCR and bench blasts were adapted to run on an IBM personal computer. They were then tested at Falconbridge's, Lockerby Mines and Inco's South Mine to determine their usefulness in a practical situation.

In consultation with Falconbridge Ltd. some structural modifications were carried out to make the bench blasting program more flexible and applicable to a wider range of design situations. Both programs worked well during testing, showing a good correlation between actual and predicted fragmentation, vibration levels and volume broken.

This report details testwork done and includes copies of the final versions of all computer codes.

1.0 RESUME

On a ajusté deux programmes informatiques conçus pour le plan d'explosions à grand diamètre de "VCR" et de filon pour être executés sur un ordinateur individuel IBM. Puis on les a soumis a des essais à Lockerby Mine de Falconbridge et à South Mine d'Inco pour déterminer leur utilité dans une situation pratique.

En consultation avec Falconbridge Ltée., on a executé quelques modifications de constitution pour que le programme d'explosion à filon soit plus flexible et qu'il ait une plus grande possibilité d'application. Les deux programmes ont fonctionné bien pendant les essais, démontrant une bonne corrélation entre la fragmentation réelle et prédite, les niveaux de vibration et le volume brisé.

Le rapport énumère les essais effectués et il inclut les épreuves des versions définitives de tous les codes informatiques.

2.0 INTRODUCTION

The use of large diameter blastholes is becoming more common in underground operations to allow mines to take advantage of the economy of increased blast size and corresponding reduced operational delays and disruptions. To improve economy, high stope heights are more frequently being blasted. Following the initial development blasts, produced using slots or circular openings and/or undercutting, two main primary blasting methods are used, these being crater retreat and regular bench blasting. The crater retreat method utilizes single cratering charges near the bottom of each hole whereas the bench blast uses the entire hole for the blast usually loaded with multiple decks.

As bench heights, and thus hole depths, become larger, the degree of hole wander increases markedly. With depths of up to 30m, hole sizes of from 125mm to 150mm exhibit some deviation, although not to such an extent that blast design is seriously affected. With increasing depth, however, hole wander becomes more significant. The result is erratic burdens and spacings being produced at the base of the blast. In some areas of the blast, where holes have converged, the blast may be greatly overloaded whereas elsewhere, where holes have diverged, burdens may be so large as to be nearly unmovable, or certainly of a size that would produce very poor fragmentation. There is even

the possibility of decks being fired out of sequence when holes converge excessively.

There are a number of instruments available which are already being used to determine the actual direction of the blastholes giving inclination and orientation with depth. These include the gyroprobe produced by Humphries, San Diego, Ca. and the Abem Reflex Fotobar produced by Atlas Copco, Sweden. The typical accuracy of these units is of the order of 0.2m per 100m of hole depth.

The Humphries unit which was planned to be used for these field tests was unavailable during the test period and so was not used. For future use it is suggested that a unit with digital storage capacity be developed so that data can be transferred directly to the computer.

Figure 1 shows a composite plan view of a blasthole layout for an actual bench blast illustrating both the locations of the blasthole collars and the blasthole toes. The hole wander is represented by the parallel dashed lines joining the top and bottom of the hole. As can be seen, there is generally no overall trend for hole direction from one hole to the next. The major contributing factors to the hole deviation are poor hole collaring, the drill and drilling techniques as well as the geological conditions.

Figure 2 highlights the result of the random hole directions. This figure presents a plan view of the bottom of

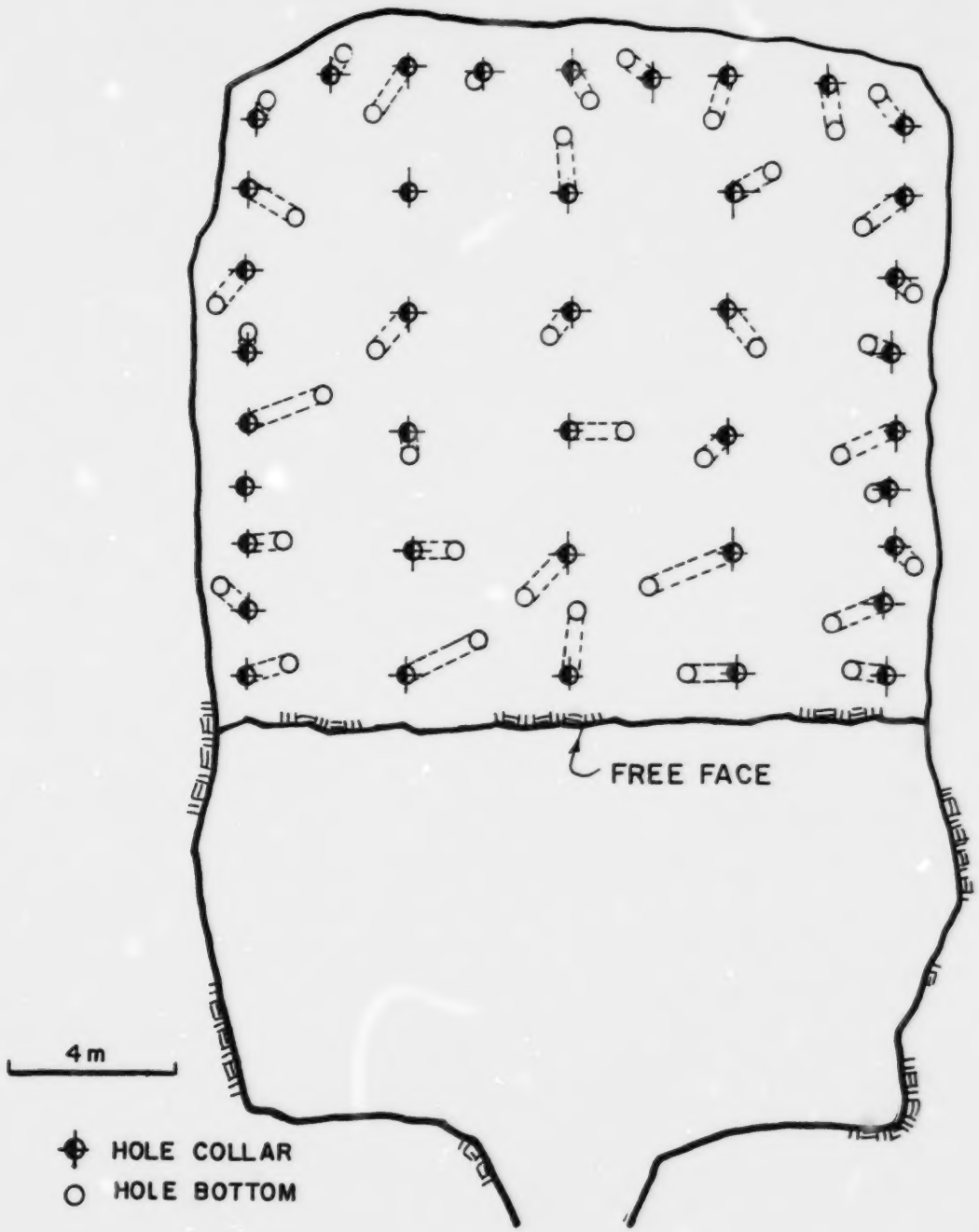


FIGURE 1 : COMPOSITE PLAN VIEW OF BLASTHOLE LAYOUT.

FIGURE 2 : PLAN VIEW OF THE LOCATIONS OF THE BOTTOM OF THE BLASTHOLES FROM FIGURE 1. .

the blastholes from Figure 1. The erratic spacings and burdens clearly indicate the difficulty in charge deck size determination and delay time selection.

A computer program has been written which will first produce a graphical model of the entire blast. The model is capable of including all of the relevant rock structure and geology. The program then calculates the optimum blast design for the particular hole layout and hole deviations. Computer output is both graphical, showing blast plans and sections with charge locations, and numerical, to present charge explosive type, size, delay period, etc.

The computer program designs the primary blasts considering such factors as:

(1) The maximum burden that can be broken for the given material and explosive type.

(2) The maximum size of explosive deck which is dictated by the vibration experienced by pillars, etc.

(3) The rock strength, work index, explosive consumption requirements given the required fragmentation desired and the preferred direction of shooting versus rock structure, etc.

(4) Short burdens are checked for the requirement of extra decking.

(5) Minimum deck separation distances are calculated.

(6) A simulation of the blast firing is programmed to select interhole delays as well as interdeck delays. Figure 3 shows a

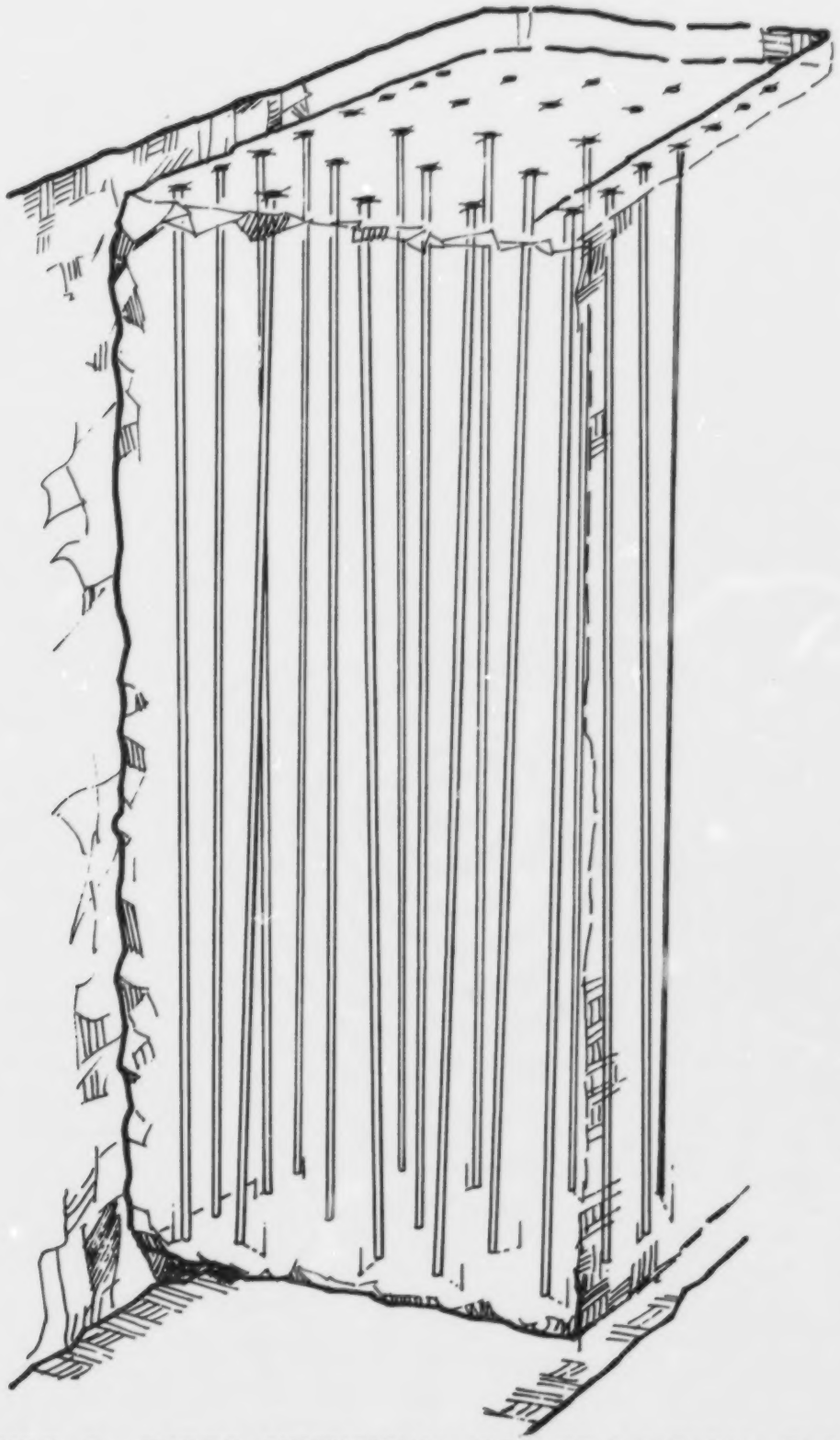


FIGURE 3: THREE DIMENSIONAL VIEW OF A TYPICAL BLAST.

three dimensional view of a typical blast. Blasthole wander can be seen to cause quite varying burdens near the bottom of the blastholes. Figure 4 shows the typical blasting sequence presently being used where one row is fired and only one hole is detonated at any one time. In this case the bottom deck of a hole would first be initiated , followed by the second, third, fourth deck, etc. and only when the entire hole has been fired would the bottom deck on the next hole be shot. This initiation method has the problem that long delays may exist between adjacent explosive decks.

Figure 5 presents an alternative approach for a single row blast. After firing two decks in the initial cut hole the next three delay periods would fire the third deck in the cut hole followed by the bottom decks in each adjacent hole. This approach is used in the design program.

In open pit blasting it is frequently found that single row blasting gives poor fragmentation. It is therefore the approach that blasting schemes are developed to safely fire multiple row shots for this type of underground blasting.

(7) The design is performed to prevent overbreak at both the top and bottom of the shot.

(8) For crater retreat blasting, the charge sizes and locations are designed, using cratering curves, relative to the blasthole spacings. The appropriate charge delays are also selected.

FIGURE 4 : THREE DIMENSIONAL VIEW OF A TYPICAL BLAST AS PRESENTLY DELAYED SHOWING EACH HOLE COMPLETELY FIRED PRIOR TO SUBSEQUENT HOLE FIRINGS.

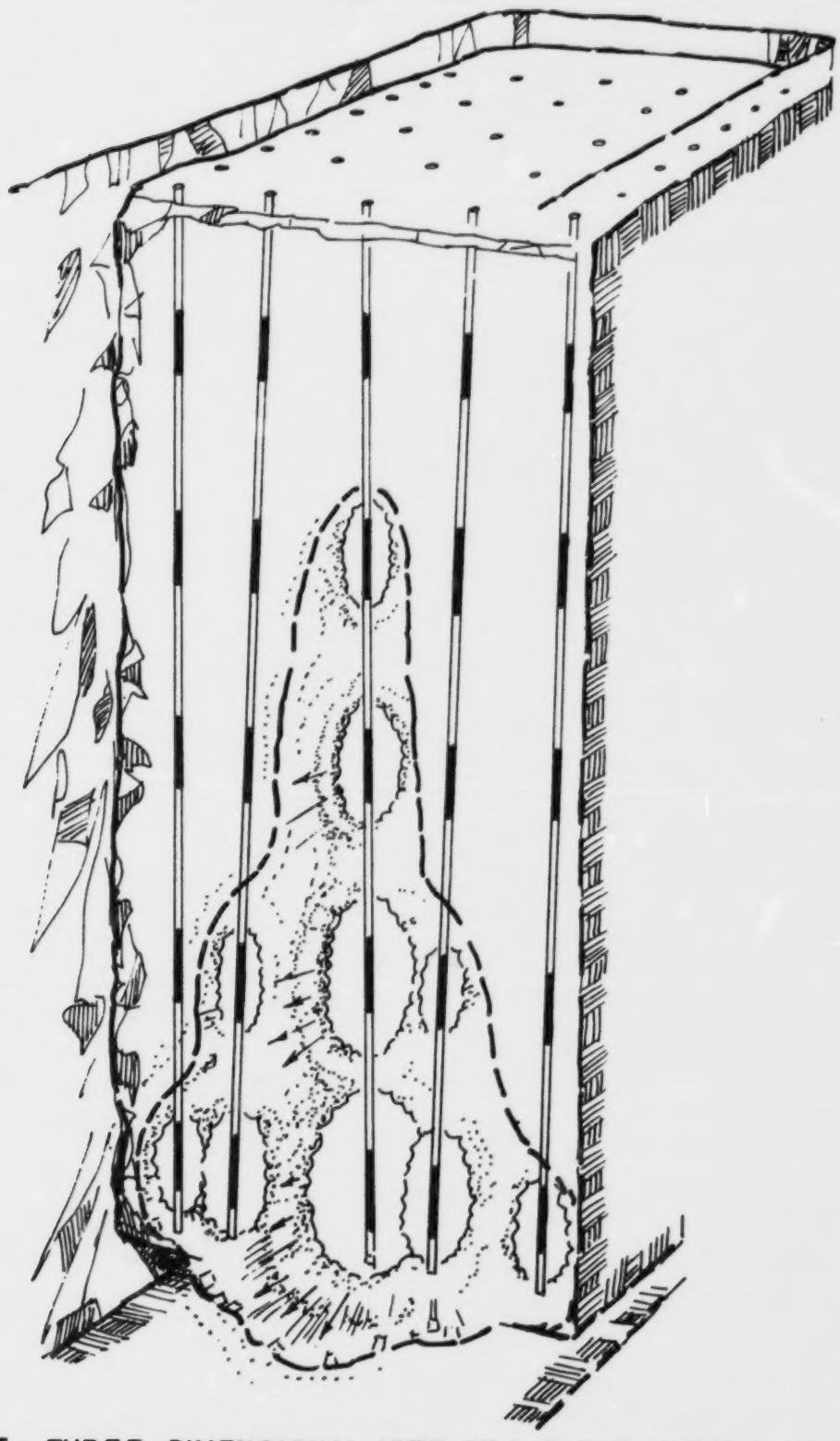


FIGURE 5: THREE DIMENSIONAL VIEW OF A BLAST SHOWING MORE THAN ONE HOLE FIRING AT ANY ONE TIME.

This type of blast design program and its various modifications provides the blasting engineer with a method of blast design evaluation prior to loading.

3.0 COMPUTER DESIGN THEORY AND COMPUTER EQUIPMENT

3.1 Theory Used

For the prediction of the craters which are formed as a result of the detonation of a charge, Livingston's crater theory was used, (Bauer, 1965 & Livingston, 1973). The basic points of this theory are given in the following. When an explosive charge of constant weight and shape is placed at different distances from a flat free face and detonated, the amount of material excavated changes with the depth of burial of the charge.

At deep depths the explosion is contained and all of the energy is used up in local crushing and seismic waves. As the depth of charge is reduced, surface slabbing is produced. Near the point where failure just starts, large pie-shaped fragments are formed in a massive material and the crater is quite shallow. As the depth of the charge is further reduced, the shape and depth of the crater changes as does the degree of fragmentation. In addition to the tensile slabs, a series of radial cracks run out from the borehole. These are due to failures starting near the explosion and which run up through the material. There is also a series of concentric circular cracks with the borehole as center. The crater dimensions and the degree of fragmentation change continuously with the depth of

burial of the charge. Associated with a certain degree of fragmentation there is also a certain level of noise and flyrock associated with the shot. In addition as the depth of a given weight of charge is reduced, the quantity of material broken passes through a maximum and at this point the degree of fragmentation is good. It is this optimum point which is of interest for production shooting. At this point flyrock is minimized and there is little noise or airblast. That is there is a minimum of wasted energy. After obtaining the optimum point for a small weight of explosive, it is then necessary to scale up to a much larger charge weight and be able to predict the results.

The following parameters are of major importance to the theory:

(a) Depth of burial of the charge. This is the distance from the center of the charge to the free surface. The depth at which surface failure just starts is called critical depth of burial (N).

(b) Strain energy factor. Livingston found that the critical depth of burial is proportional to the one-third power of the charge weight ($W^{1/3}$). The constant of proportionality (E) is called strain energy factor. If the factor E is known the critical depth for any charge weight can be calculated.

(c) The depth ratio is the ratio of the depth of burial to the critical depth for the same weight of charge.

Hence the depth of burial of the charge dc = ΔN or dc = $\Delta E W^{1/3}$, which is the general equation.

The depth ratio can be correlated to any scaled parameter of the crater such as the scaled crater depth or the scaled crater radius. The shape of the resulting curves is shown in Figure 6. This figure gives the scaled crater depth as a function of the depth ratio. It follows that the deepest crater results at a depth ratio of approximately 0.3. At this depth ratio the fragmentation is good and the use of the energy of the explosive optimum. It follows that for optimum blasting results the charge has to be such that the depth ratio is close to or less than the optimum depth ratio.

Cratering curves can also be plotted versus the scaled depth of burial, (D.O.B.), (Figure 6A) where D.O.B. = $d/W^{1/3}$ (d = depth of charge burial, W = weight of charge). This approach does not require the calculation of the depth ratio or the factor E, as the test results are plotted directly. The relationship between the depth ratio and the scaled depth of burial is described by the equation - D.O.B. = $\Delta \frac{N}{W^{1/3}}$

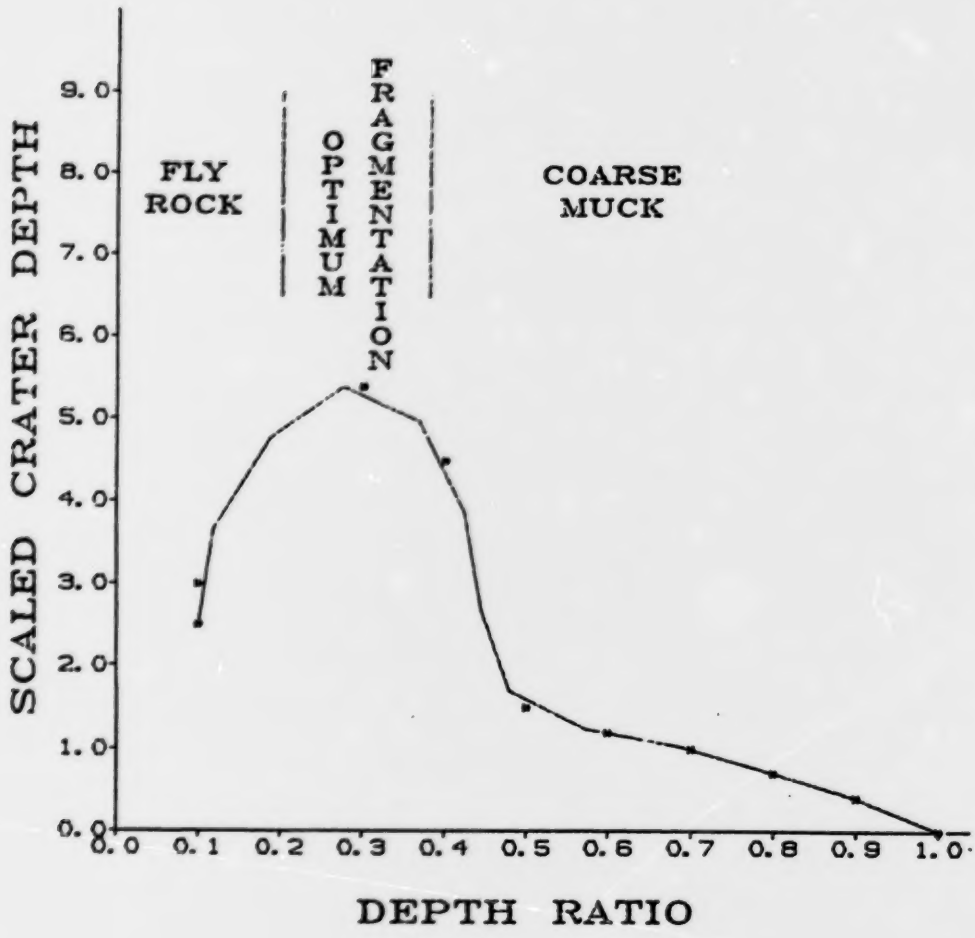


FIGURE 6 : TYPICAL SCALED CRATER DEPTH - DEPTH RATIO CURVE.

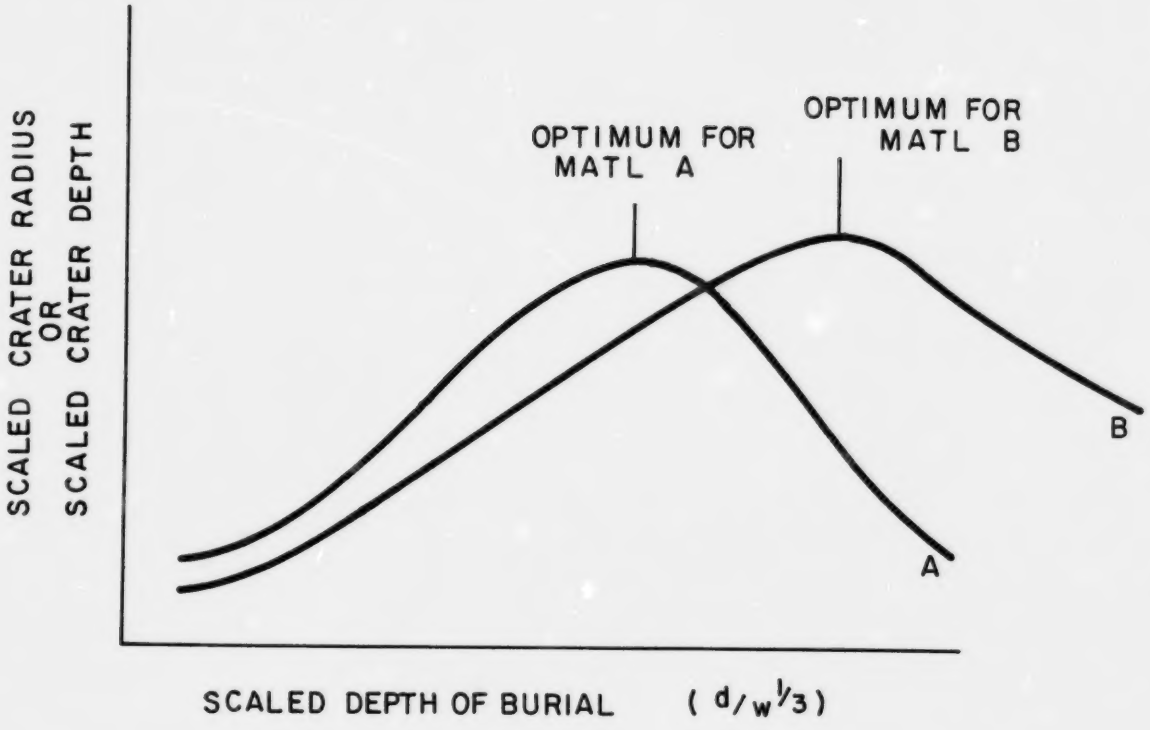


FIGURE 6A : CRATER CURVES USING SCALED DEPTH OF BURIAL.

3.2 Vibration Checks

In recent years the question of what constitutes a valid criterion for blasting damage has been discussed by a number of authors. Extensive statistical reviews have been made of published vibration data to determine which of the blast induced parameters, such as particle displacement, velocity or acceleration, best measures the damaging effects of a vibrational wave on a structure. The current conclusion is that damage can best be correlated with the peak particle velocity of the wave regardless of the direction of motion; longitudinal, vertical or transverse.

Historically several formulae have been developed to give peak particle velocity. The formula for spherical charges which is used in the programs is widely accepted and was developed by Devine, (Devine , 1966). The formula used is:

$$V = k(R/W^{1/3})^m$$

where V the peak particle velocity

R the distance between the explosion and the recording site

W the weight or the charge

k,m site factors which must be determined at the particular mine site.

3.3 Comparison Between Usually Accepted Design Practice and Reality

One of the major disadvantages of the application of Livingston's theory today is that the generally accepted design practice tends to ignore the fact that a charge detonating at an earlier period creates a free face for the subsequent detonations. The generally accepted case which is shown at the top of Figure 7 assumes that the only active free face is the initial one.

However the actual case resembles the second drawing of Figure 7. Moreover if the charge detonation at a later period is very close to the free face created by an earlier detonation, the result will be flyrock and waste of energy. Therefore charge 2 (Figure 7 third drawing) will not break the volume of rock which it was supposed to break, leaving excessive burdens for the next charge.

In the programs presented in this report an attempt was made to simulate the reality.

Refering to Figure 8, at each depth of burial (AB) (depth from the closest free face) the crater radius can be calculated by using the scaled crater radius - depth ratio curve. Therefore the maximum distance at which rock is broken can be found (distance AC in Figure 8) for every position of the charge. This distance which is called slant distance indicates the

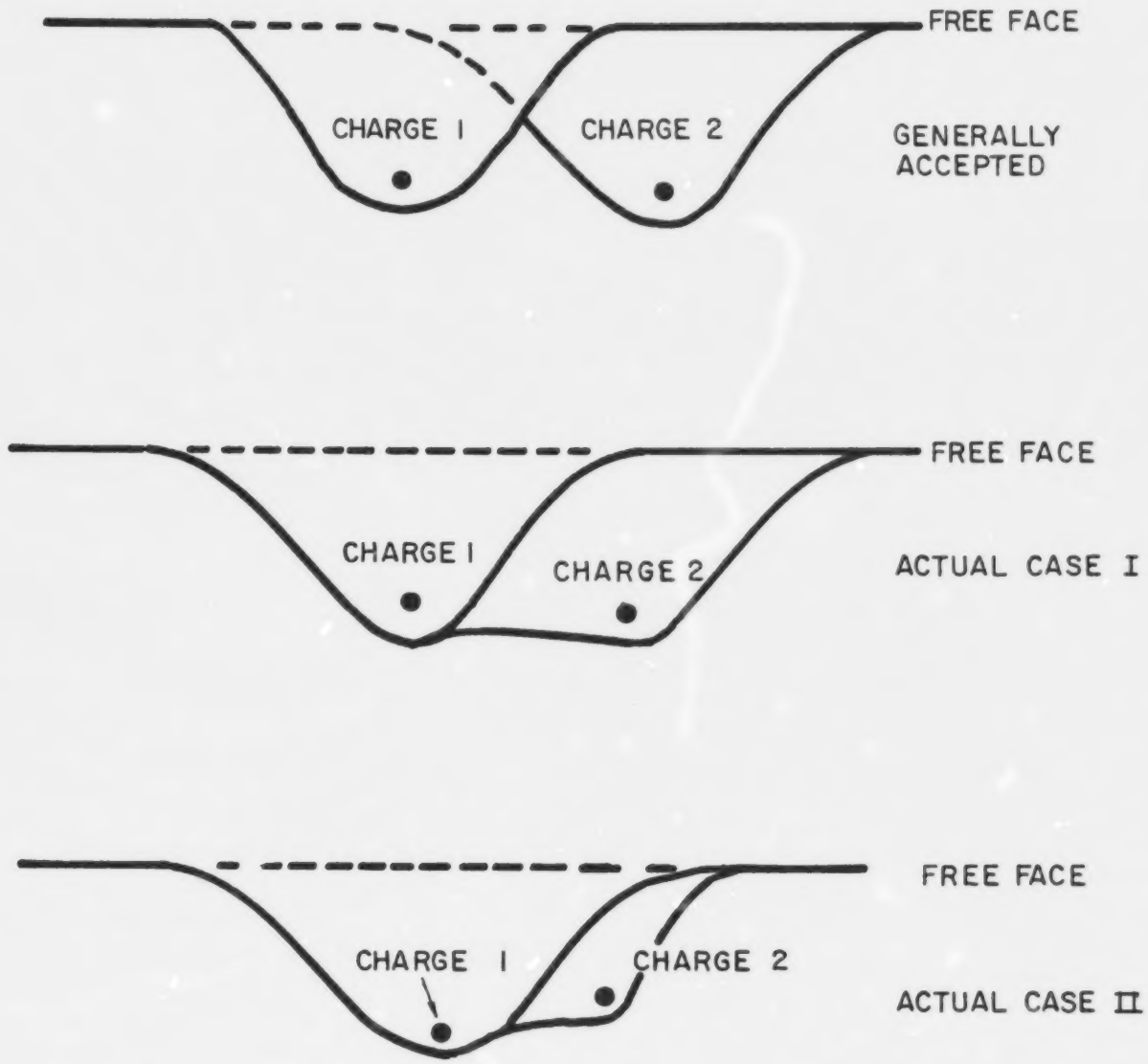


FIGURE 7 :
COMPARISON BETWEEN THE GENERALLY ACCEPTED DESIGN PRACTICE AND TWO ACTUAL CASES .

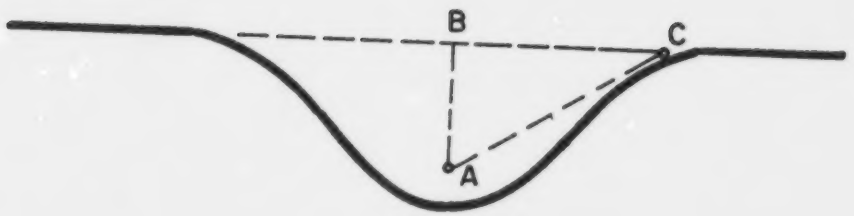


FIGURE 8 : MAXIMUM DISTANCE FROM A CHARGE IN WHICH ROCK IS BROKEN.

maximum distance which the charge is going to break due to its position with respect to the free faces surrounding it.

It is believed that this approach is reasonable since the closest face offering a relief to the blast determines the dimensions of the resulting crater.

3.4 Blast Design Flowchart

The program is split into two main parts as regards the flowchart. These parts correspond to the large diameter blasthole benching operation and the vertical crater retreat method. They will be dealt with separately in this section.

Large Diameter Blasthole Benching

Figures 9(A) and 9(B) present the general flowchart for the large diameter blasthole benching portion of the program.

After initializing the variables, the input data are read. Data can be read in either metric or imperial units. Output from data read in metric units is produced in metric units while imperial unit input data generates output in imperial units.

The initial calculation of the separation between explosives decks is then made. Factors in the calculation include the rock type and other geological factors resulting in

PROGRAM LDBB — GENERAL FLOWCHART

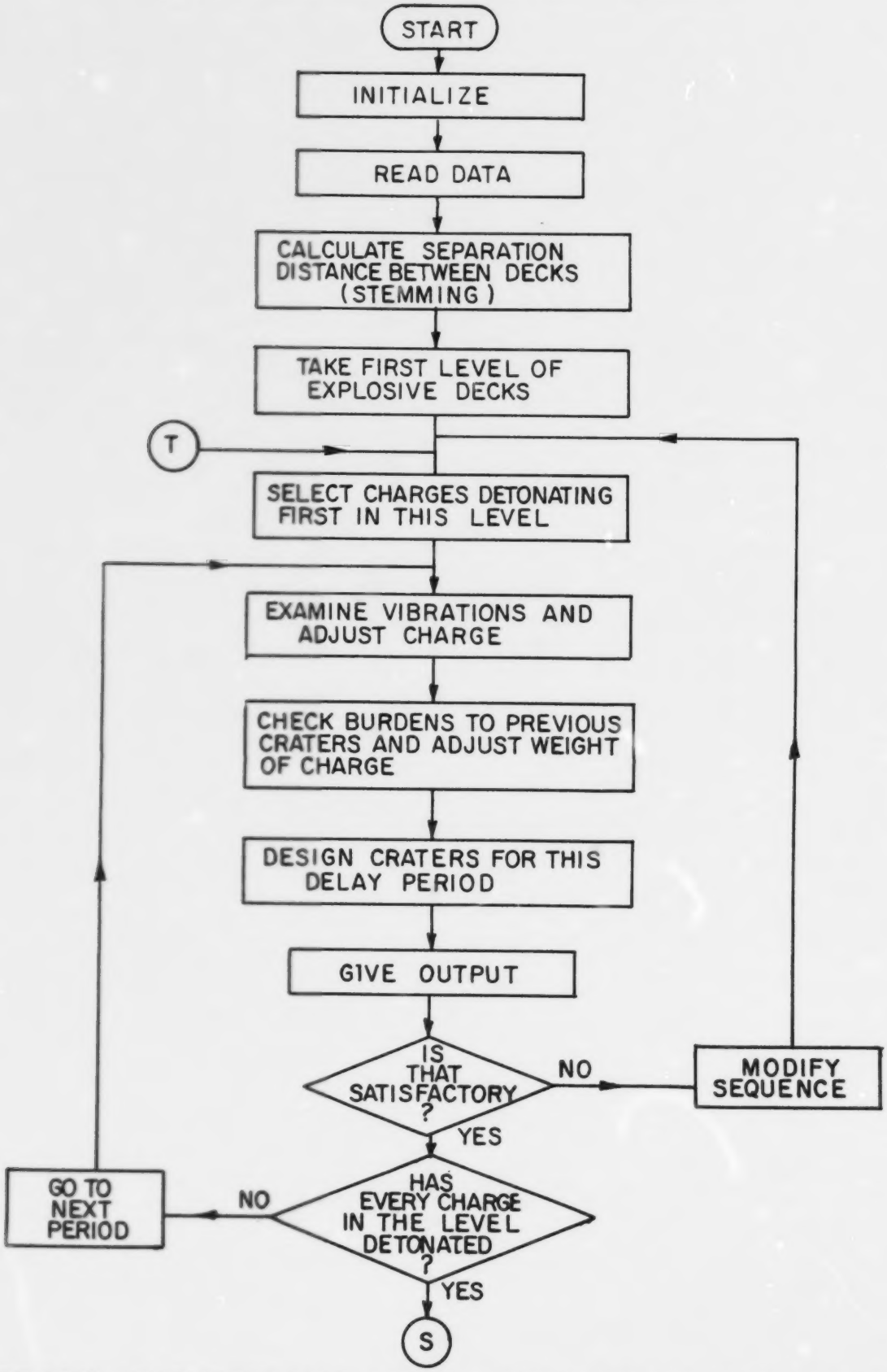


FIGURE 9(A): THE FIRST PART OF THE LARGE DIAMETER BLASTHOLE BENCH BLAST DESIGN PROGRAM FLOWCHART.

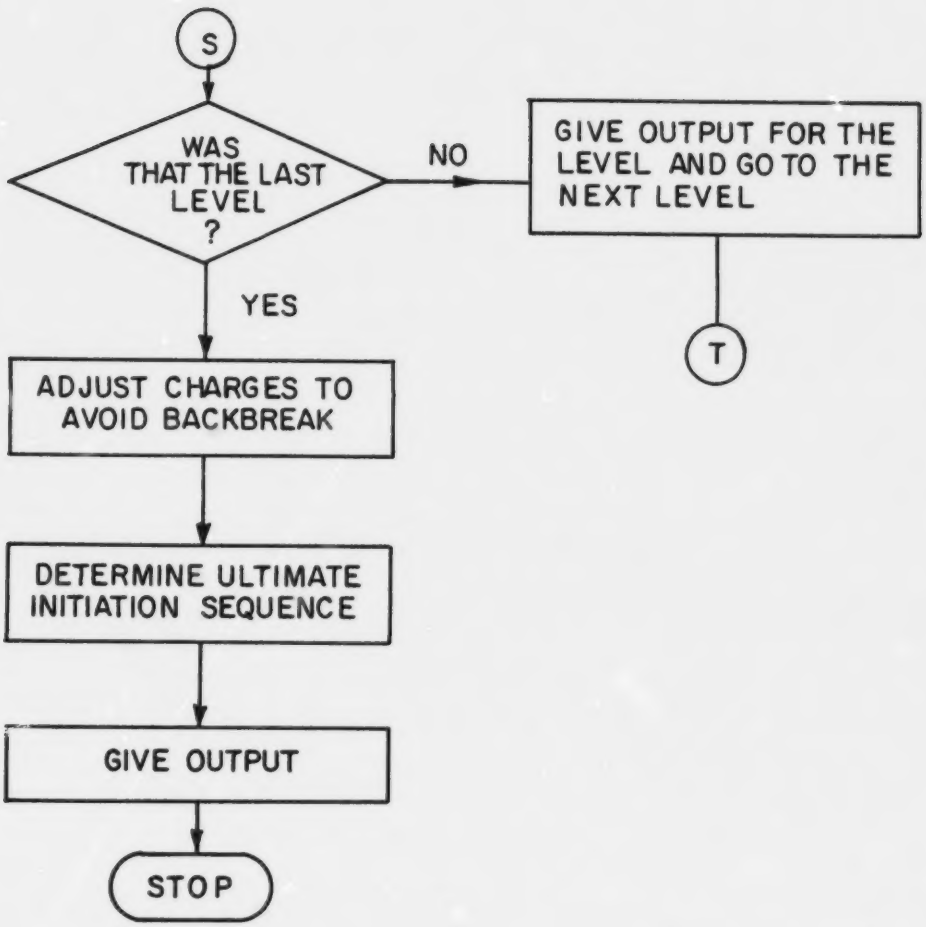


FIGURE 9(B) : THE SECOND PART OF THE LARGE DIAMETER BLASTHOLE BENCH BLAST DESIGN PROGRAM FLOWCHART.

a required energy level for the material to produce good fragmentation. The influence of the different decks is accommodated by consideration of the fragmentation produced off the end of each deck charge, and in particular, the fragmentation produced by the end 8 charge diameters. This section of charge is considered separately as the shape of the stress wave from off the end of the charge is near spherical in shape and thus is typical of a spherical charge. The 8 charge diameter length is the longest charge that can be fired with results appearing to be similar to those that would be generated by an actual spherical charge itself.

Finally the deck separation is also considered in the light of the current experience which has shown the possibility of sympathetic detonation of delayed decks if the distance between them is too small. The best estimate available at the time of writing is that the minimum deck separation should be no less than 16 times the hole diameter. This can be changed in the program later should a better relationship be established.

The next sequence of events is conducted on each successive charge and level of decks.

There are two methods of selecting the sequence of charge detonations. This may be inputted by the programmer or it may be generated by the program itself. The manual option has been introduced in the program to allow for overriding of the

optimized self generated sequence should there be specific reasons for so doing by the mine engineer.

The charges are then examined for vibrations and adjustment is made if required. The burdens are checked to the previous craters and adjustments are made if necessary. The craters are then predicted according to these changes in the particular deck under consideration. The output for the process is then presented.

For the manual sequencing technique, the programmer is then asked if the output received to this point is satisfactory? If it is not the preceding sequence of steps is repeated until the programmer is satisfied with the results. When the programmer is satisfied, or if the automatic mode is used, the program then checks to see if every charge in the level has been detonated. If they have not, again the preceeding sequence of events is repeated until all charges have been considered. Then the program proceeds.

The next question finds out if all of the different charge levels have been considered. If they have not the preceding sequence is repeated for the next level, and so on, until all of the charges in the blast have been considered.

When all of the charges have been detonated the program then determines any special design with respect to wall control to avoid backbreak.

Finally the ultimate initiation sequence is determined and the output for the program is given.

Large Diameter Blasthole Benching Simulation

During testwork at Falconbridge Limited, it was found that a blast simulation rather than an automated design was more useful to field engineers. To this end the bench blasting design program was modified to allow the user to specify charge weights, locations and firing sequence. The output summarizes this input and predicts fragmentation and the extent of the broken area. This new program (called LSIM) can be used in conjunction with the design program to simulate deviations from the optimum design generated.

Vertical Crater Retreat Method

Figure 10 presents the general flowchart for the vertical crater retreat method portion of the program.

Again the variables are initialized and the data are read. Again either metric or imperial units may be used.

A similar option to the one used in the bench blasting is available for the vertical crater retreat, this being the option to produce an optimized computer generated firing sequence

PROGRAM VCRM - GENERAL FLOWCHART

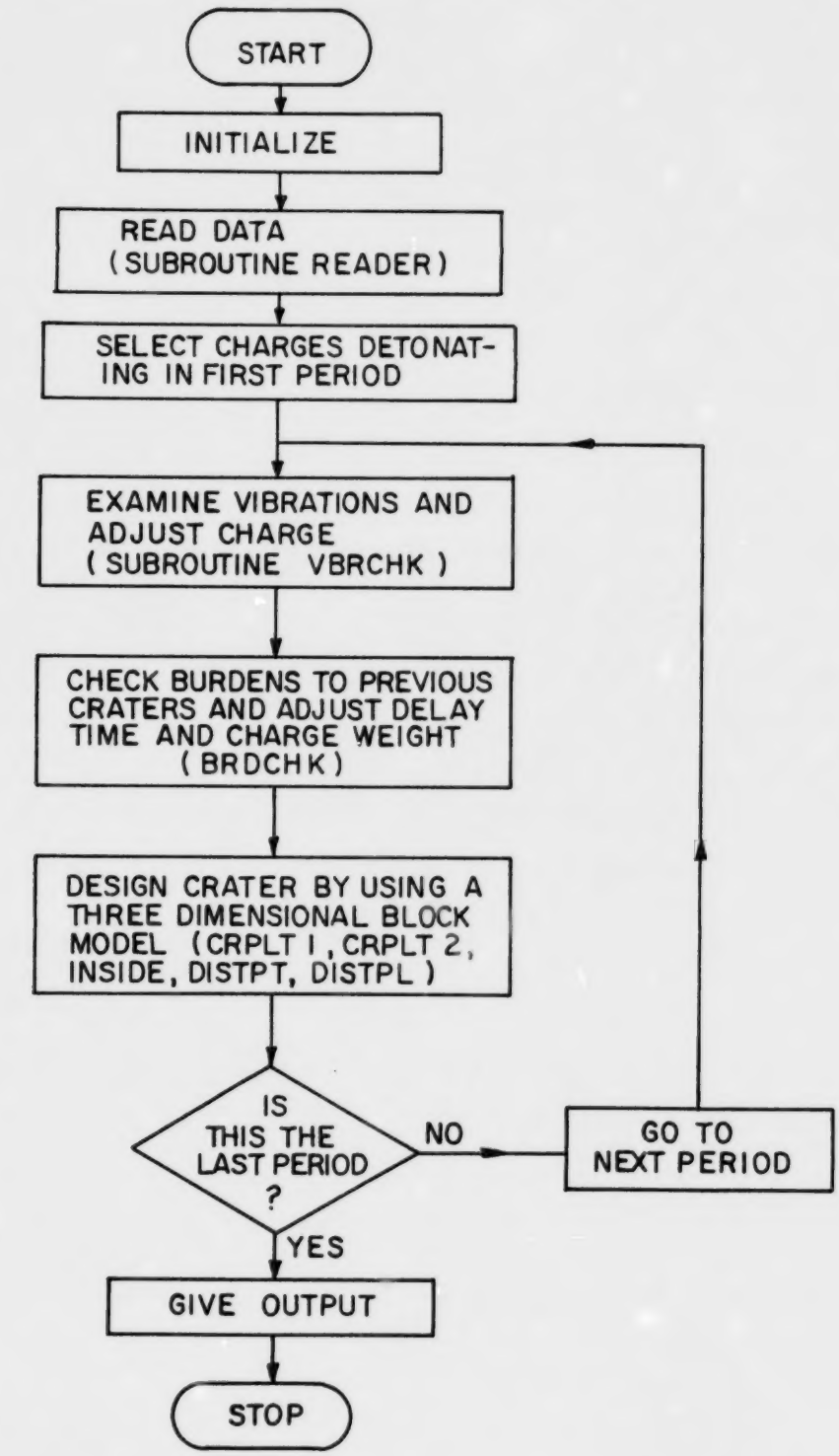


FIGURE 10: THE VERTICAL CRATER RETREAT METHOD BLAST DESIGN PROGRAM FLOWCHART.

for the charges, or to override this sequence and input a manual selection based on other factors .

The sequence of events in the vertical crater retreat design is now similar to a deck for the bench blasting program. The charge is examined for vibrations and adjusted if required. The burdens are then checked to previous craters and any adjustments in charge weight and delay are made. The new crater is then designed using, in this case, a three dimensional block model.

The program then checks if this is the last period to be detonated, if not the process is repeated. Once all of the charges have been detonated the blast is complete and the output is supplied.

Program Listing

A full listing of the program, split into four parts is presented in the Appendix E. The four parts are:

1. Vertical Crater Retreat Method Design
2. Large Diameter Bench Blast Design
3. Large Diameter Bench Blast Simulation
4. Graphics Output Generator Program for Both Design Programs

3.5 Computer Software and Hardware

The programming language is VS FORTRAN which is compatible with most micro computers currently available.

The graphics used is the IBM Kernel System prepared by IBM Limited.

The computer used is the IBM PC XT.

The graphics terminal used is the IBM Enhanced Graphics Colour Monitor.

The plotter used is the Hewlett Packard 7470A

The program can be easily modified for use on most other currently available computers.

4.0 DATA DESCRIPTION

This section shows how data are inputted into the program as well as presents the necessary exec files to run the program.

4.1 Input Data

The input data to the programs can be divided into four categories:

(a) Data related to the geometry of the blast. These data are:

- The coordinates of the holes
- The location of the free face
- The coordinates of the points in which vibrations will be checked.

(b) Data related to Livingston's crater theory. Data of this kind are:

- The scaled crater depth - depth ratio curve
- The scaled crater radius - depth ratio curve.

(c) Data related to the explosive. These data are:

- The weight strength of the explosive used in the tests and the explosive used in the blasting operations in the stope
- The density of the explosive.

(d) Other data such as:

- The diameter of the blastholes
- The number of the blastholes
- The site factors for the vibration checks
- The maximum acceptable levels of the peak particle velocity at different points
- For the bench blast simulation program deck weights, separation distance and firing sequence.

The method of the creation of the data files is given in the user's manual of the programs.

4.2 Data for Graphics Programs

Graphics output is given by using programs PGRAPH and PLBLAST. PGRAPH provides cross-sections and plan views of the blast block while PLBLAST gives the after blast profile of the VCR stope. The exec files for the use of these programs can be found in Appendix E. The input data for these programs are prepared by the programs used for the design of the blast (VCRM ,

LDBB). The user has to respond to a few questions asked by the programs.

5.0 PROGRAM EVALUATION

After conversion to run on the IBM personal computers, arrangements were made to test the programs at Falconbridge Ltd.'s, Lockerby Mine and Inco Metals Company's South Mine in Sudbury, Ontario. These tests were designed to determine how the programs performed during normal field use and if modifications were needed.

The normal procedure for each blast was to gather data for input to the program the day before the blast and then to run the program overnight. Each program requires approximately 1/2 hour to set-up files for operation and several hours to run, depending on the size of the blast. The results of the program were then evaluated with respect to the engineering layout. The day of the blast was spent preparing and installing vibration monitoring equipment. Loading sheets were checked against what was actually done and any necessary changes to program input was noted. Following the blast, the vibration, fragmentation and blast perimeter data were recorded and compared to values predicted by the program.

5.1 Vibration Monitoring

Vibration levels close to the blast were recorded using Geosource triaxial geophones which measured peak particle

velocity. Recording of the vibration traces was achieved using an FM tape recorder at Falconbridge and a digital recorder at Inco. These traces were transfered to an oscilliscope and were analyzed to determine the peak particle velocity. Photographs of the monitoring equipment and a typical trace can be seen in Figures 11 to 16.

5.2 Fragmentation

Fragmentation of the blasted rock is predicted by the program using the Kuz-Ram model (see Appendix C). This model was developed for open pit bench blasting and is suited for modelling underground bench blasting as well. The 50% passing size for the blasted muck was measured from photographs (see Figure 17). To supplement this technique measurements were also taken underground to estimate fragmentation. Fragmentation was not modelled for the VCR blasts.

5.3 Blast Perimeter

The extent of each blast was measured and marked on plans or sections by the mine survey crew. These were compared with perimeters shown on computer generated plans.

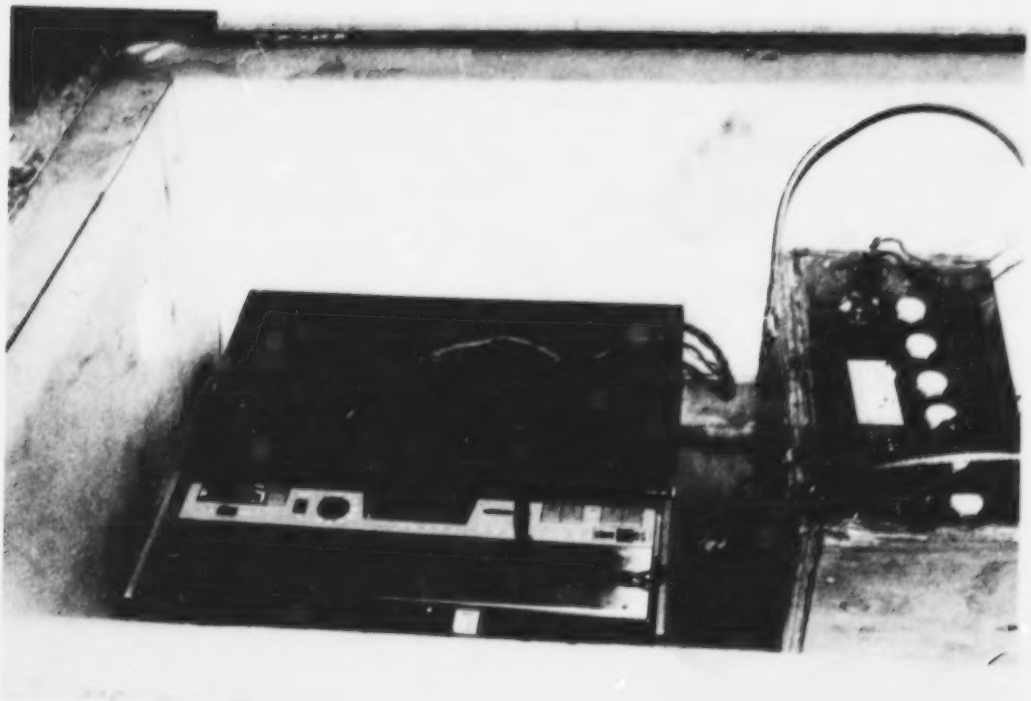


FIGURE 11: THE RACAL FM RECORDER.

FIGURE 12: TRIAXIAL GEOPHONE MOUNTED TO CROSSCUT WALL.

FIGURE 13: DIGITAL MONITOR AND BATTERIES WITH GEOPHONE ATTACHED (OFF WALL).

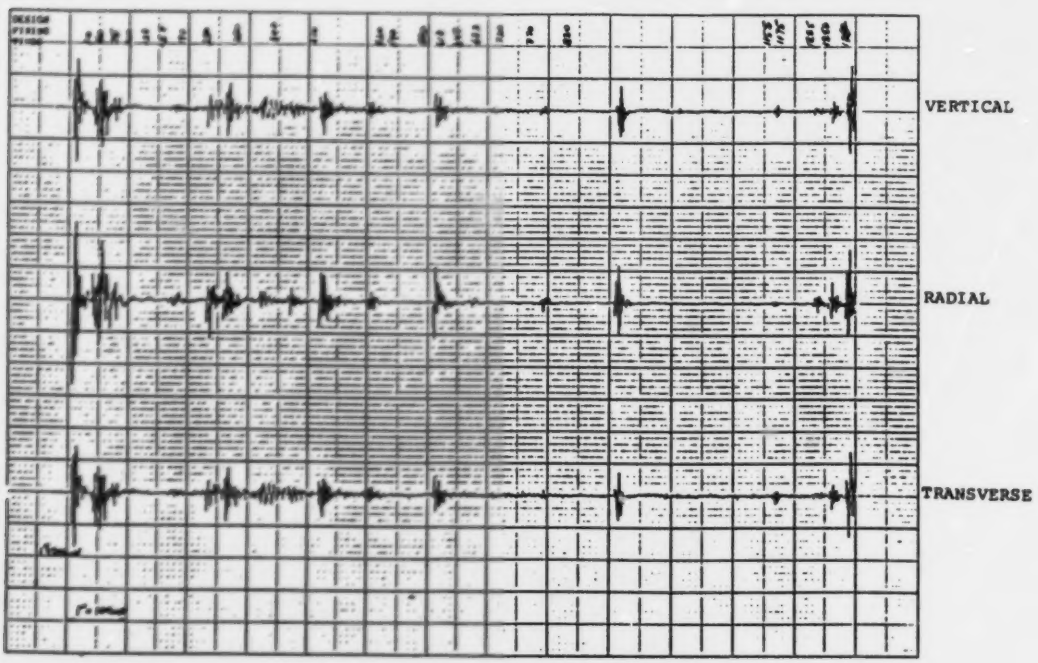


FIGURE 14: TYPICAL VIBRATION TRACE FROM THE TRIAXIAL GEOPHONE.

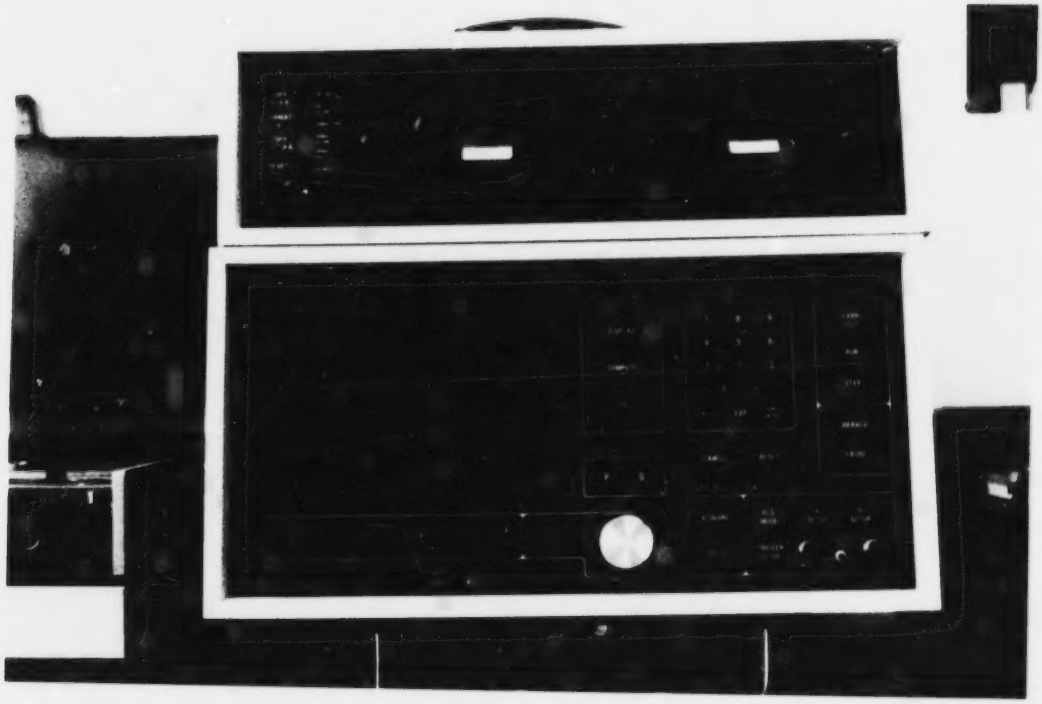


FIGURE 15: THE NORLAND PROWLER OSCILLOSCOPE USED FOR ANALYSIS.

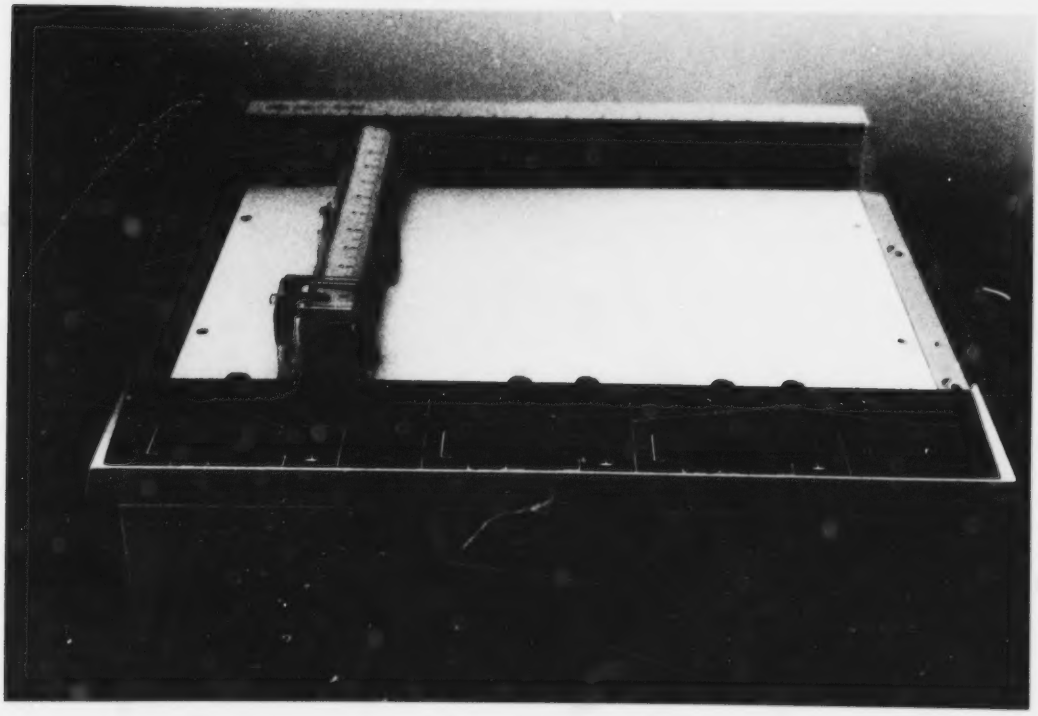


FIGURE 16: THE HEWLETT PACKARD XY RECORDER USED TO GENERATE HARD COPIES OF VIBRATION TRACES.

FIGURE 17A: FALCONBRIDGE 31-151 STOPE MUCK, TAPE = 5 FT. (1.54m)

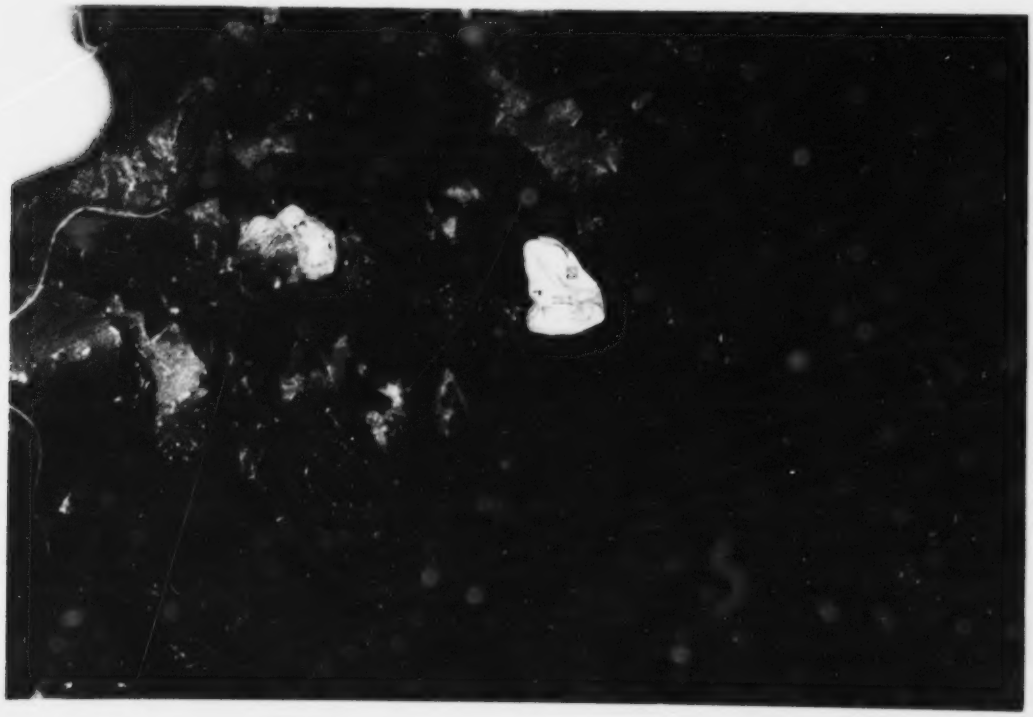


FIGURE 17B: INCO 808.6 STOPE MUCK, TOP TO BOTTOM OF PACK = 1.1 FT. (0.34m)

5.4 Test Stope 26-150, Lockerby Mine

The test procedures will be outlined using Lockerby's 26-150 stope as an example. The blast which was simulated was a 7 hole bench blast. Three bootleg holes were also blasted but were not considered for simulation purposes. The blast layout, overcut plan and undercut plan are shown in Figures 18 to 20. From these plans hole coordinates were measured and the slot outline was found. Deck weights and locations, and the firing sequence are obtained from the layout. These data for input to the program is summarized in Tables 1 to 4.

The output from the program (Tables 5 to 11 and Figures 21 and 22) tabulates charge weights, locations and firing sequence for each deck. It also produces an outline of the broken area at two levels within the stope. In these representations the broken area is shown as dots and the holes are asterisks. The levels are established to be at the middle of each deck level, starting with level one through the bottom deck.In this example the weights are shown in pounds and the lengths in feet. The break shown here correlates well with what was seen underground except for some cratering effects which can be explained by post-blast sloughing.

Fragmentation is also predicted here. The fifty percent passing size predicted by the model is close to that seen in the stope but there was a slight underestimation of oversize

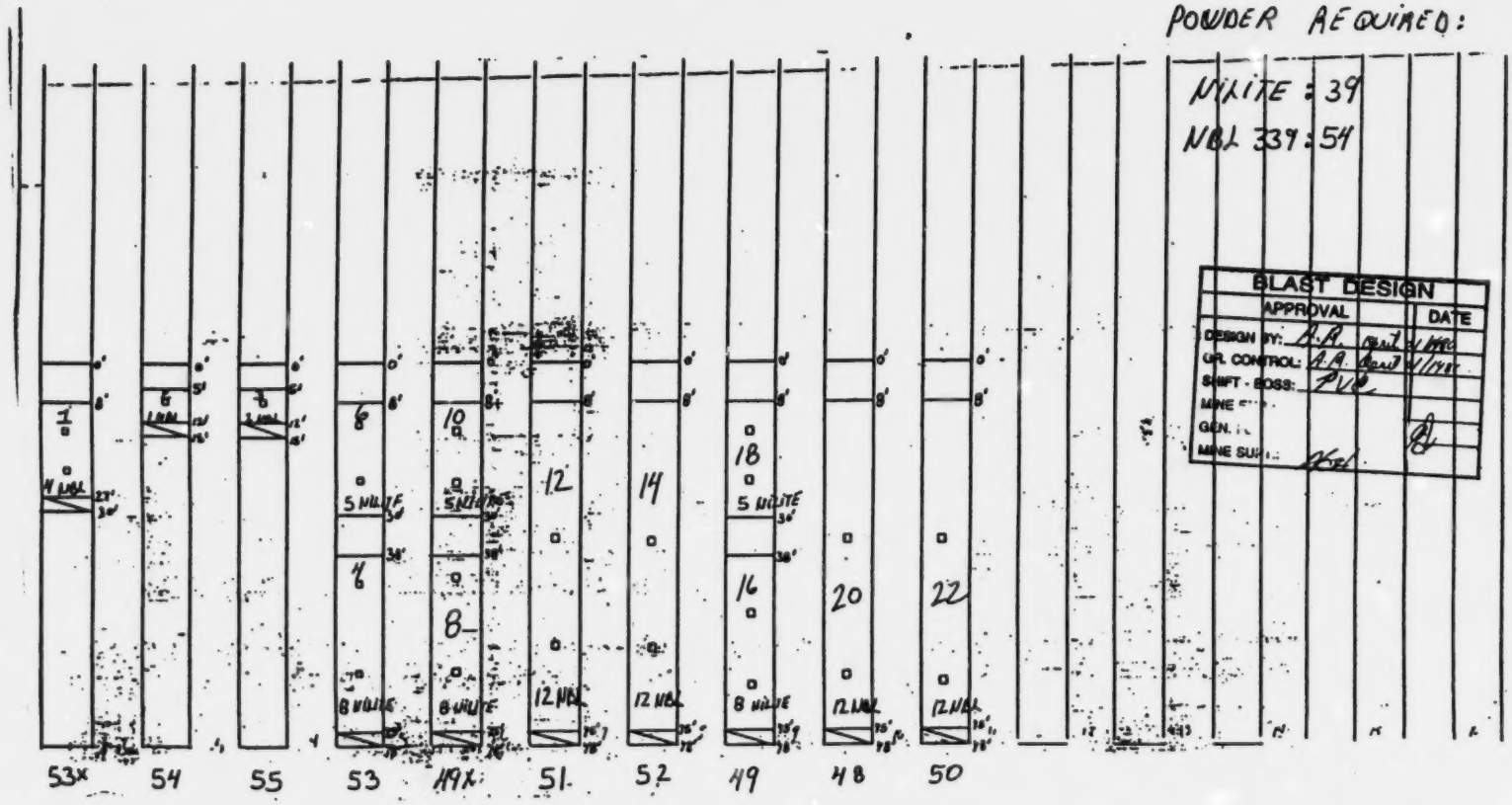
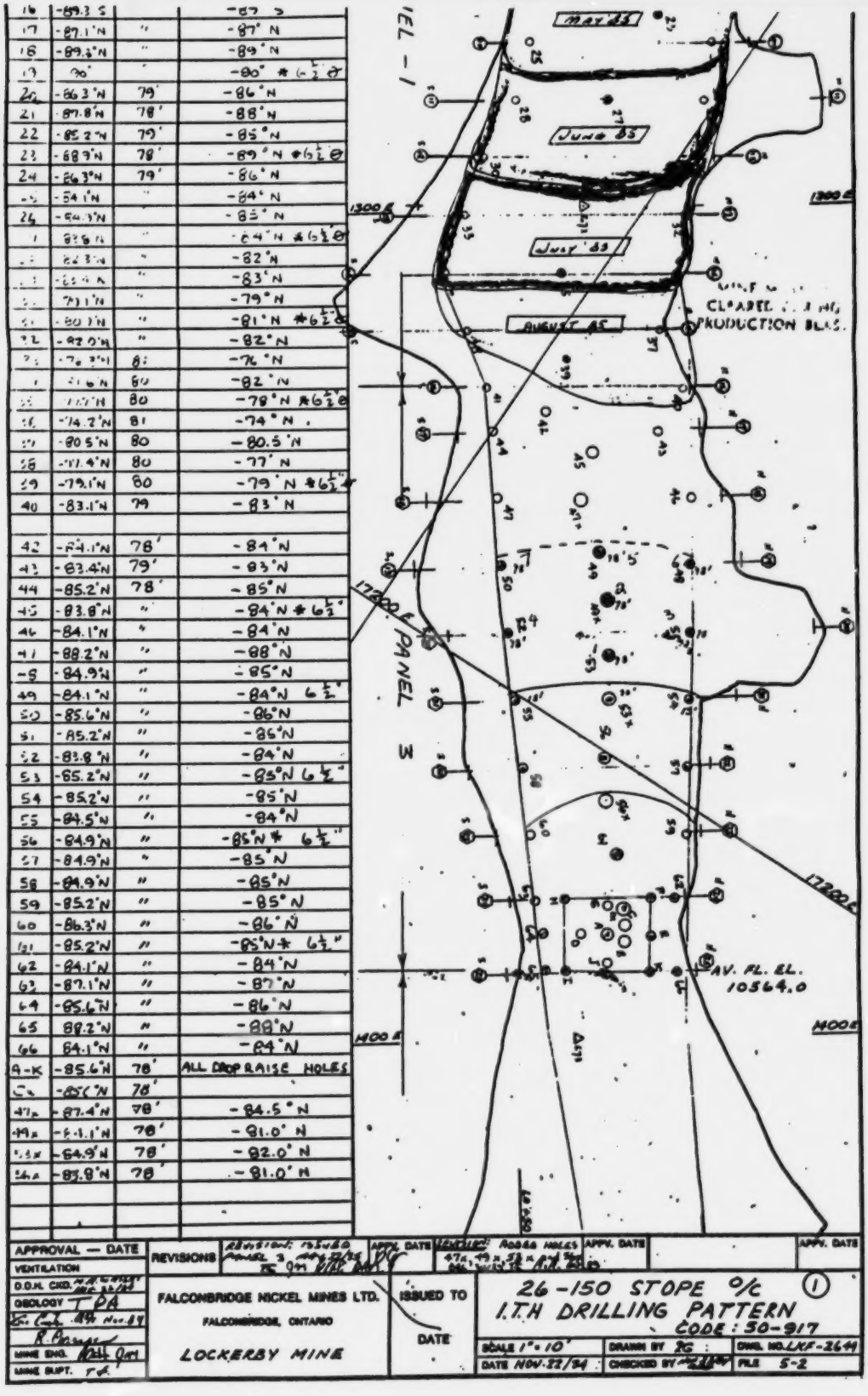


FIGURE 18: LOADING INSTRUCTIONS, 26-150 STOPE



16	-89.3 S		-87 S
17	-87.1'N	"	-87° N
18	-89.2'N	"	-89° N
19	90°		-90° # 6½ Ø
20	-86.3'N	79'	-86° N
21	-87.8'N	78'	-88° N
22	-85.2'N	79'	-85° N
23	-88.7'N	78'	-89° N #6½ Ø
24	-86.3'N	79'	-86° N
25	-84.1'N	"	-84° N
26	-84.3'N		-85° N
1	83.6 N	"	-84° N #6½ Ø
2	82.3'N	"	-82° N
3	-83.4'N	"	-83° N
4	79.1'N	"	-79° N
5	-80.1'N	"	-81° N #6½ Ø
12	-82.0'N	"	-82° N
13	-76.3'N	81	-76° N
14	81.6 N	80	-82° N
15	77.7'N	80	-78° N #6½ Ø
16	-74.2'N	81	-74° N
17	-80.5'N	80	-80.5° N
18	-77.4'N	80	-77° N
19	-79.1'N	80	-79° N #6½"
40	-83.1'N	79	-83° N
42	-84.1'N	78'	-84° N
43	-83.4'N	79'	-83° N
44	-85.2'N	78'	-85° N
45	-83.8'N	"	-84° N #6½"
46	-84.1'N	"	-84° N
47	-88.2'N	"	-88° N
48	-84.9'N	"	-85° N
49	-84.1'N	"	-84° N 6½"
50	-85.6'N	"	-86° N
51	-85.2'N	"	-86° N
52	-83.8'N	"	-84° N
53	-85.2'N	"	-85° N 6½"
54	-85.2'N	"	-85° N
55	-84.5'N	"	-84° N
56	-84.9'N	"	-85° N # 6½"
57	-84.9'N	"	-85° N
58	-84.9'N	"	-85° N
59	-85.2'N	"	-85° N
60	-86.3'N	"	-86° N
61	-85.2'N	"	-85° N # 6½"
62	-84.1'N	"	-84° N
63	-87.1'N	"	-87° N
64	-85.6'N	"	-86° N
65	88.2'N	"	-88° N
66	84.1'N	"	-84° N
A-K	-85.6'N	78'	ALL DROP RAISE HOLES
[illegible]	-85.6'N	78'	
47A	-87.4'N	78'	-84.5° N
49A	-81.1'N	78'	-81.0° N
53A	-84.9'N	78'	-82.0° N
54A	-83.8'N	78'	-81.0° N

FIGURE 19: DRILLING PLAN, 26-150 OVERCUT

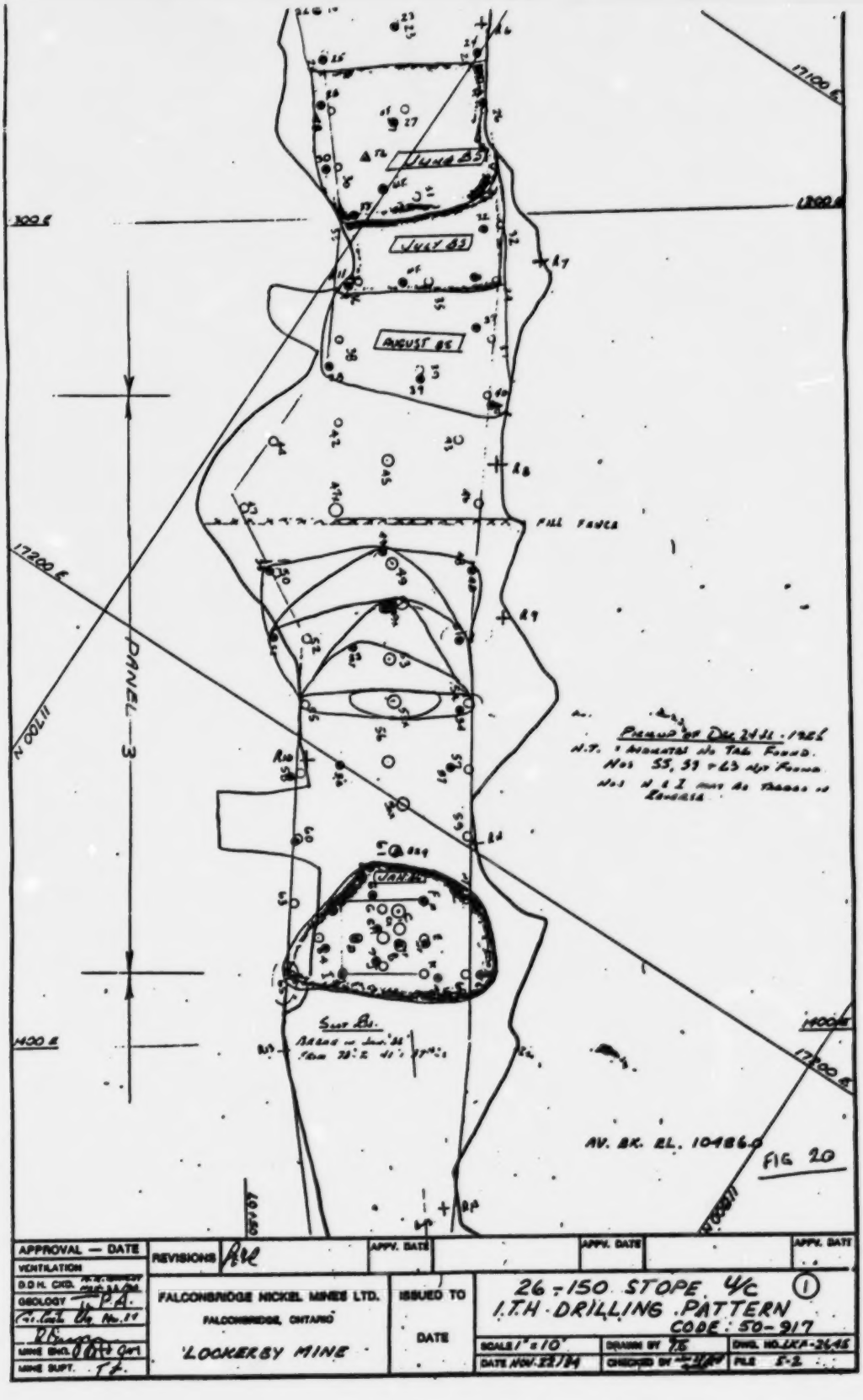


FIGURE 20: DRILLING PLAN, 26-150 UNDERCUT

26-150 STOPE HOLE COORDINATES

HOLE NO.	ROW	COLUMN	x(ft)	y(ft)	z(ft)
1(53)	1	1	24.5	1353	10486
			26.5	1352	10564
2(49x)	2	2	24	1346.5	10486
			30.5	1347.5	10564
3(51)	2	3	34	1350	10486
			39	51.5	10564
4(52)	2	4	12.5	1350	10486
			17	1351	10564
5(49)	3	2	23.5	1340.5	10486
			30	1340.5	10564
6(48)	3	3	34	1342	10486
			41	1343	10564
7(50)	3	1	12	1342	10486
			16.5	1342.5	10564

TABLE 1: BLASTHOLE COORDINATES OF TOE AND COLLAR OF BENCH.

SLOT OUTLINE		x(ft)	y(ft)	z(ft)
Line:	1	35	1358	10486
		40.5	1358.5	10564
	2	24	1356.5	10486
		31	1357.5	10564
	3	12.5	1357.5	10486
		20	1358.5	10564
	4	122.5	1370	10486
		20	1370	10564
	5	24	1370	10486
		31	1370	10564
	6	35	1370	10486
		40.5	1370	10564

- see users manual for description of slot outline data development.

TABLE 2: COORDINATES OF THE SLOT OUTLINE.

REFERENCE DATA

26-150 STOPE

5.0	1335	10486	REFERENCE POINT, x y z coordinates (ft)
40	35	78	STOPE WIDTH, LENGTH, DEPTH (ft)
0.0			REFERENCE ANGLE (degrees)
7			NUMBER OF HOLES

TABLE 3: REFERENCE POINT AND STOPE DIMENSIONS.

26-150 STOPE

HOLE #	SEPARATION FROM TOE TO 1ST DECK (ft)	WEIGHT (lbs)	EXPLOSIVE	DELAY SEQUENCE	SEPARATION BETWEEN DECKS (ft)	WEIGHT (lbs)	EXPLOSIVE	DELAY SEQUENCE
1	3	440	N	1	8	275	N	2
2	3	440	N	3	8	275	N	4
3	3	198	NBL	5	0	198	NBL	5
4	3	198	NBL	6	0	198	NBL	6
5	3	440	N	7	8	275	N	8
6	3	198	NBL	9	0	198	NBL	9
7	3	198	NBL	10	0	198	NBL	10

Nilite FR = N ρ = 0.031 lb/cu.in. Weight Strength (ANFO = 1) = 1
NBL 339 = NBL ρ = 0.015 lb/cu.in. Weight Strength (ANFO = 1) = .92

Powder Factor = $\frac{3927 \text{ lbs}}{3780 \text{ tons}}$ = 1.037 lb/ton

= 0.11 lb/cu.ft.

Burden x spacing = 8 ft. x 10 ft.

TABLE 4: INTERACTIVE INPUT.

26-150 STOPE

PROGRAM LDBB OUTPUT

WRITTEN FOR THE DESIGN OF THE BLAST IN AN UNDERGROUND STOPE USING THE LARGE DIAMETER BLASTHOLE BENCHING METHOD

EXPLOSIVE USED: N
DENSITY: 0.0310 LBS/CUBIC INCH
HOLE DIAMETER: 6.5000 INCH

HOLE NUMBER	DELAY PERIOD
1	1
2	3
3	5
4	6
5	7
6	9
7	10

TABLE 5: INITIATION SEQUENCE IN LEVEL #1.

HOLE NUMBER	WEIGHT (LBS)	EXPLOSIVE TYPE
1	440	N
2	440	N
3	198	NBL
4	198	NBL
5	440	N
6	198	NBL
7	198	NBL

NBL = NBL 339 (LOW DENSITY ANFO)

N = Nilite FR (ANFO)

TABLE 6: WEIGHT OF EXPLOSIVE IN THE DECKS IN LEVEL #1.

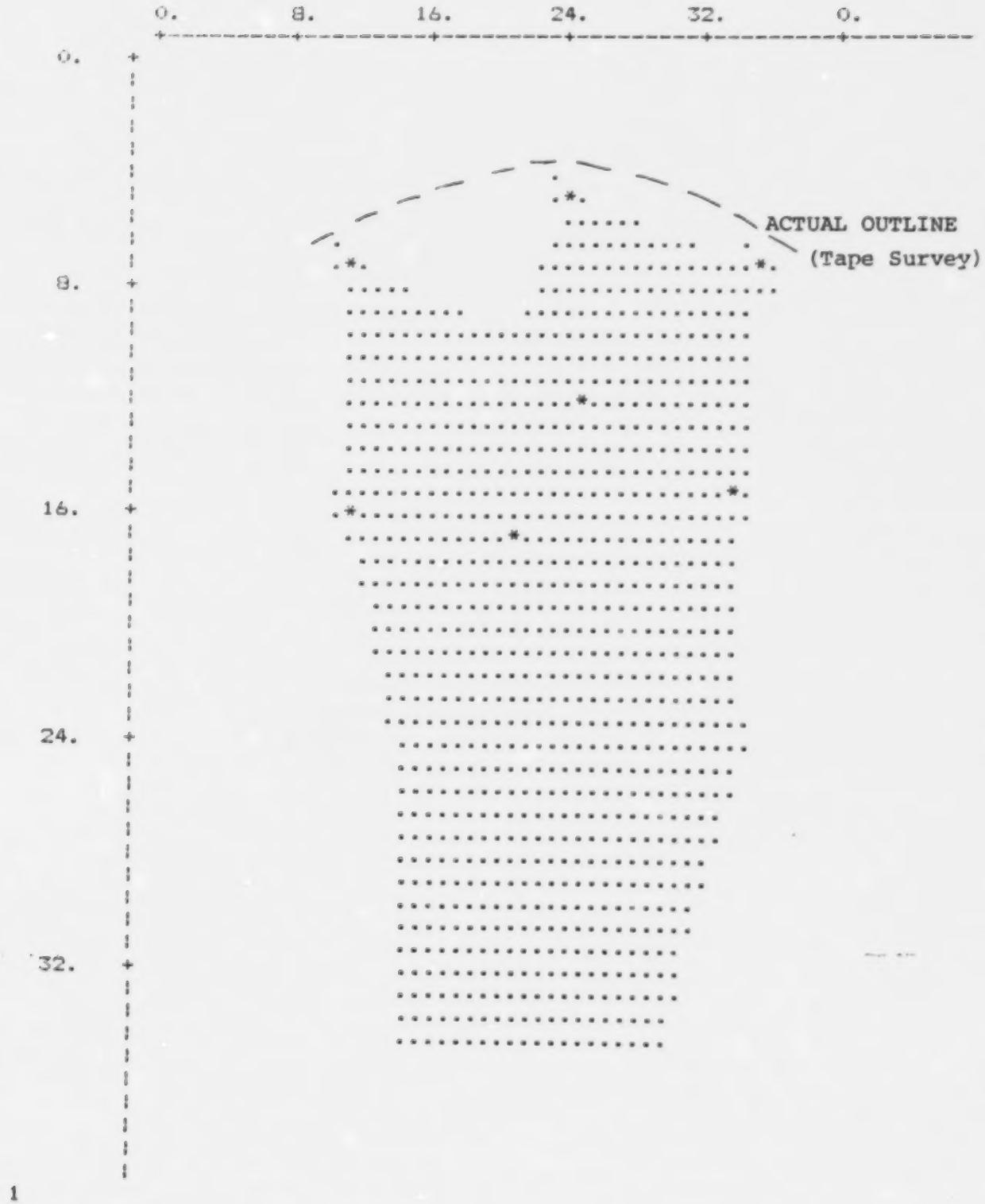


FIGURE 21: PLAN VIEW AT DEPTH 75 FT. (LEVEL 1)

HOLE NUMBER	DELAY PERIOD
1	2
2	4
3	6
4	7
5	9
6	10
7	11

TABLE 7: INITIATION SEQUENCE IN LEVEL #2.

HOLE NUMBER	WEIGHT (LBS)	EXPLOSIVE TYPE
1	275	N
2	275	N
3	198	NBL
4	198	NBL
5	275	N
6	198	NBL
7	198	NBL

NBL = NBL 339 (LOW DENSITY ANFO)

N = Nilite FR (ANFO)

TABLE 8: WEIGHT OF EXPLOSIVE IN THE DECKS IN LEVEL #2.

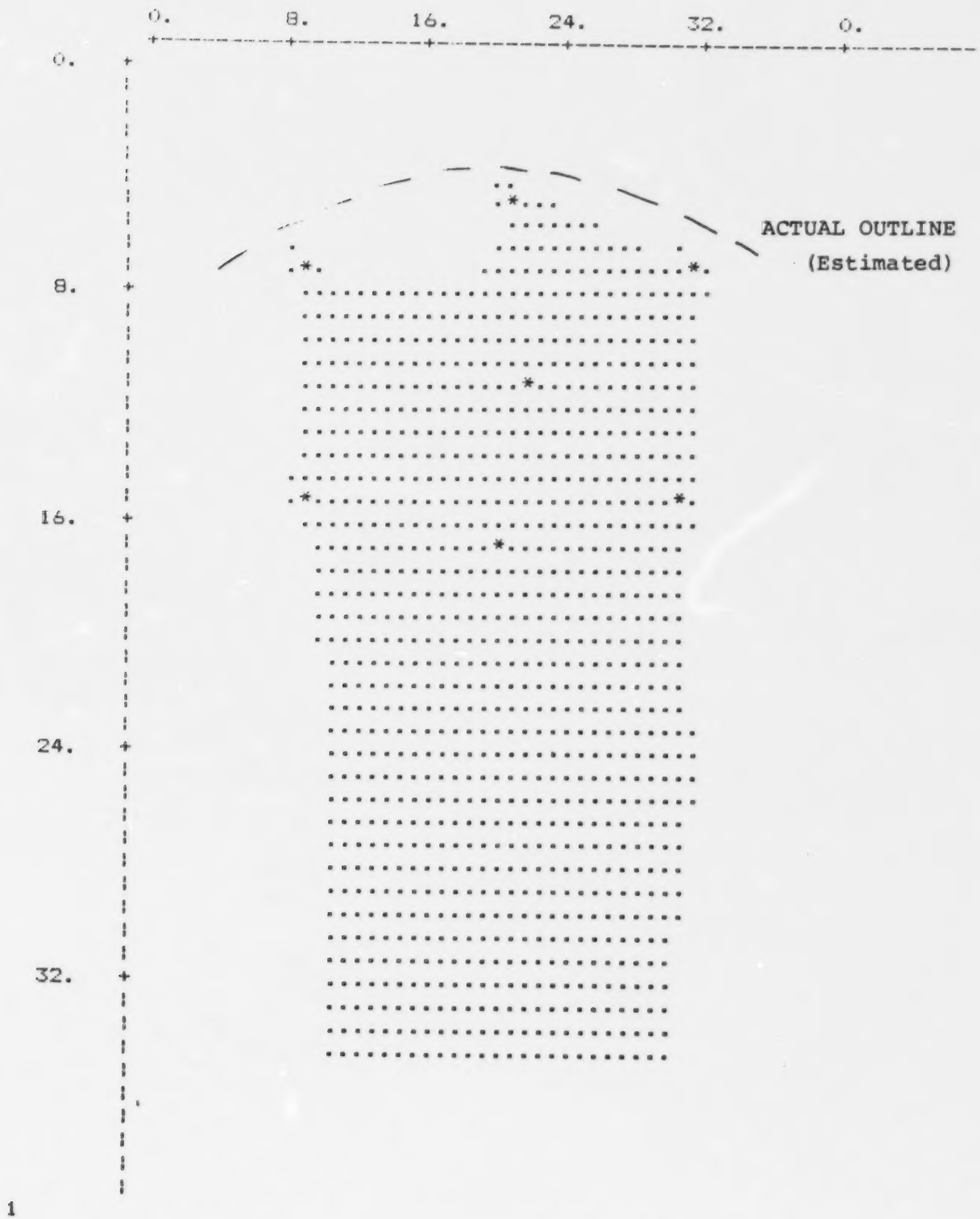


FIGURE 22: PLAN VIEW AT DEPTH 31 FT. (LEVEL 2)

TOTAL WEIGHT OF EXPLOSIVE: 3729 LBS

DELAY NUMBER	QUANTITY
1	1
2	1
3	1
4	1
5	1
6	2
7	2
8	0
9	2
10	2
11	1

TABLE 9: EXPLOSIVE AND DELAY USAGE SUMMARY.

HOLE #	CHARGE LOCATION (DEPTH TO BOTTOM OF CHARGE ft)	CHARGE WEIGHT (lbs)	DELAY SEQUENCE	EXPLOSIVE TYPE
1	75	440	1	N
	31	275	2	N
2	75	440	3	N
	31	275	4	N
3	75	198	5	NBL
	42	198	6	NBL
4	75	198	6	NBL
	42	198	7	NBL
5	75	440	7	N
	31	275	9	N
6	75	198	9	NBL
	42	198	10	NBL
7	75	198	10	NBL
	42	198	11	NBL

NBL = NBL 339 (LOW DENSITY ANFO)
N = Nilite FR (ANFO)

TABLE 10: INSTRUCTIONS FOR LOADING.

80.00 PERCENT PASSING SIZE	=	27.4	INCHES
70.00 PERCENT PASSING SIZE	=	19.7	INCHES
60.00 PERCENT PASSING SIZE	=	14.5	INCHES
50.00 PERCENT PASSING SIZE	=	10.6	INCHES
40.00 PERCENT PASSING SIZE	=	7.5	INCHES
30.00 PERCENT PASSING SIZE	=	5.0	INCHES
20.00 PERCENT PASSING SIZE	=	2.9	INCHES

TABLE 11: PREDICTED FRAGMENTATION.

FRAGMENTATION

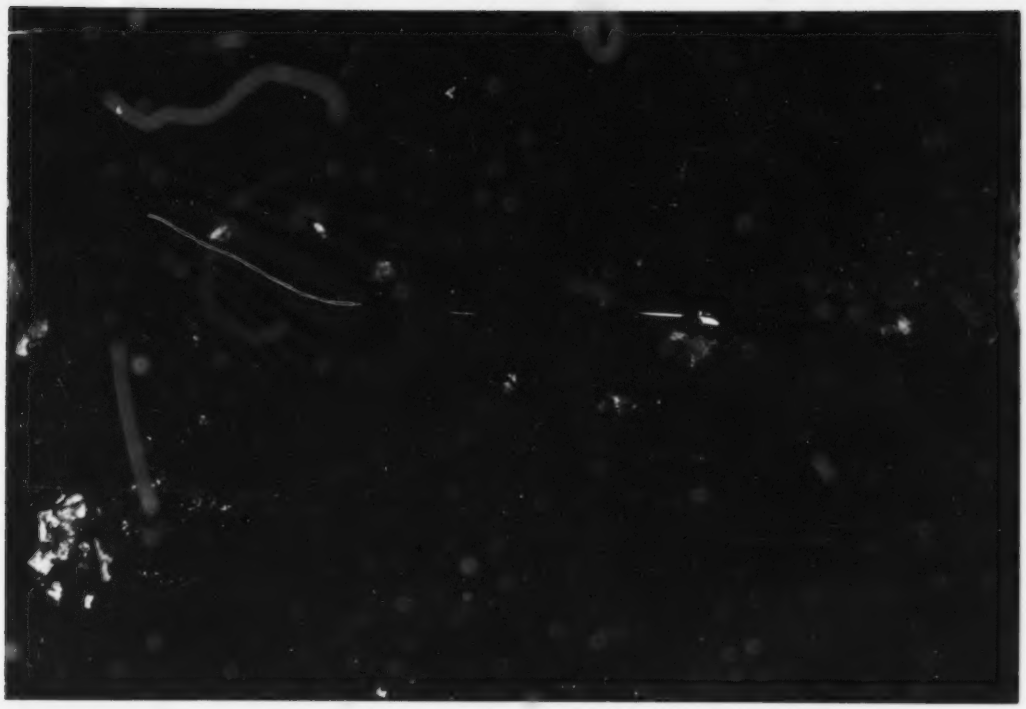


FIGURE 23: 26-150 STOPE UNDERCUT - TAPE 5 FT.(1.27 m) EXTENDED
50% PASSING SIZE IS ESTIMATED TO BE 11.8 inches.

by the model. The actual 80% passing size is estimated to be approximately one meter. (Figure 23). Graphics output (Figure 24) can provide cross and long section views and plan views at any elevation.

Vibration monitoring was performed using the RACAL FM tape recorder and two triaxial geophones. The geophones were set up in a crosscut adjacent to the stope, 105 and 140 feet from the blast. The peak particle velocities measured here were 2.6 and 3.9 inches/second respectively. These velocities are lower than those predicted by the computer program (3.3 in/sec and 4.9 in/sec) which could be explained by geological factors, loose rock or an obstructed path between the geophones and the blast. Vibration records are shown in Figure 25.

5.5 Modifications to Programs

After the first two tests at Lockerby Mine it was decided that a simulation program for bench blasting would be more suitable for field use than an automated design program. Since production patterns are usually blasted at less than 100% efficiency to ensure good fragmentation, the optimum design was not favoured.

Specific modifications were:

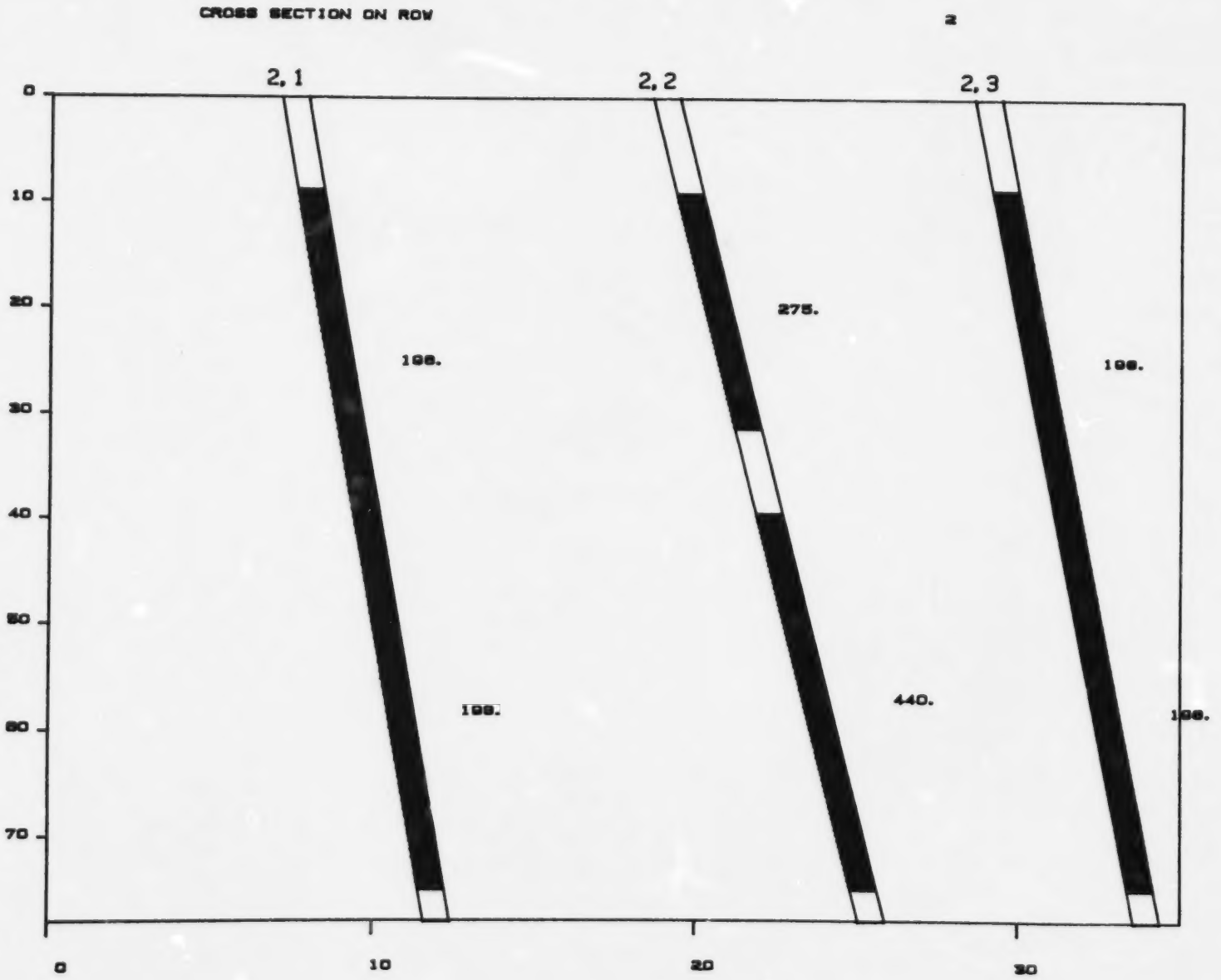


FIGURE 24: GRAPHICS OUTPUT EXAMPLE 26-150 STOPE

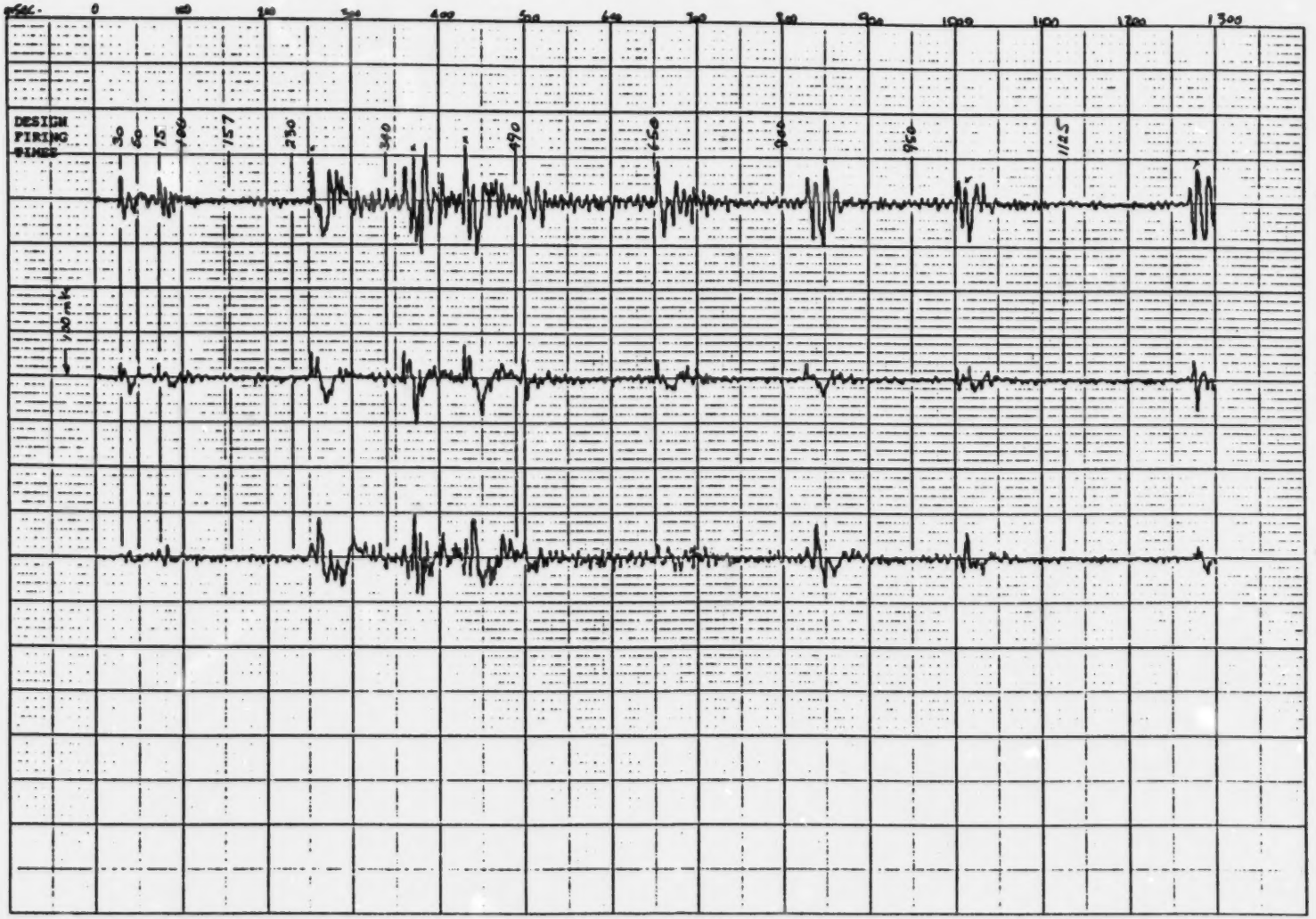


FIGURE 25A: VIBRATION TRACE, STOPE 26-150 (o to 1300 ms)

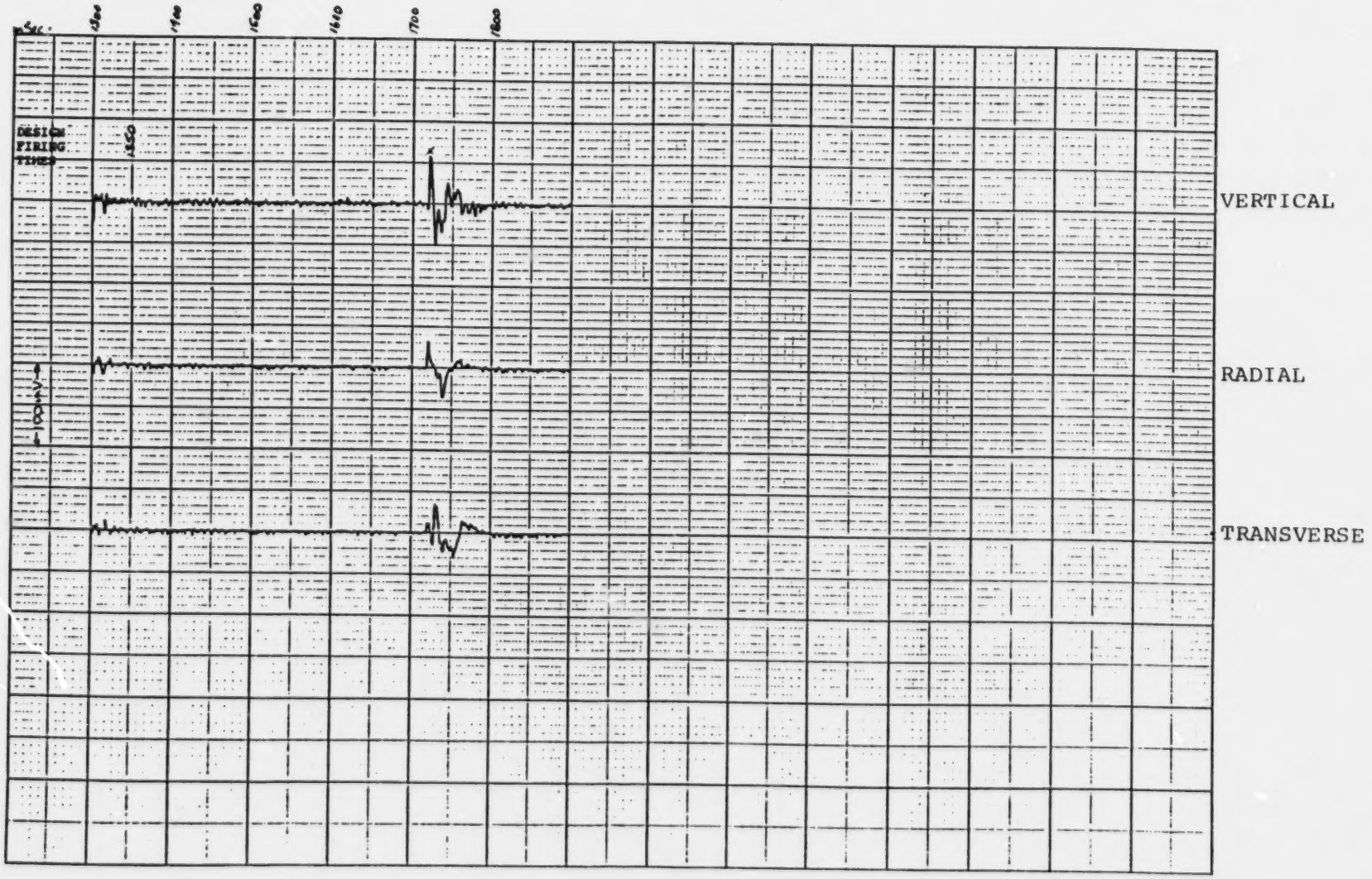


FIGURE 25B: VIBRATION TRACE, STOPE 26-150 (1300 to 1800 ms)

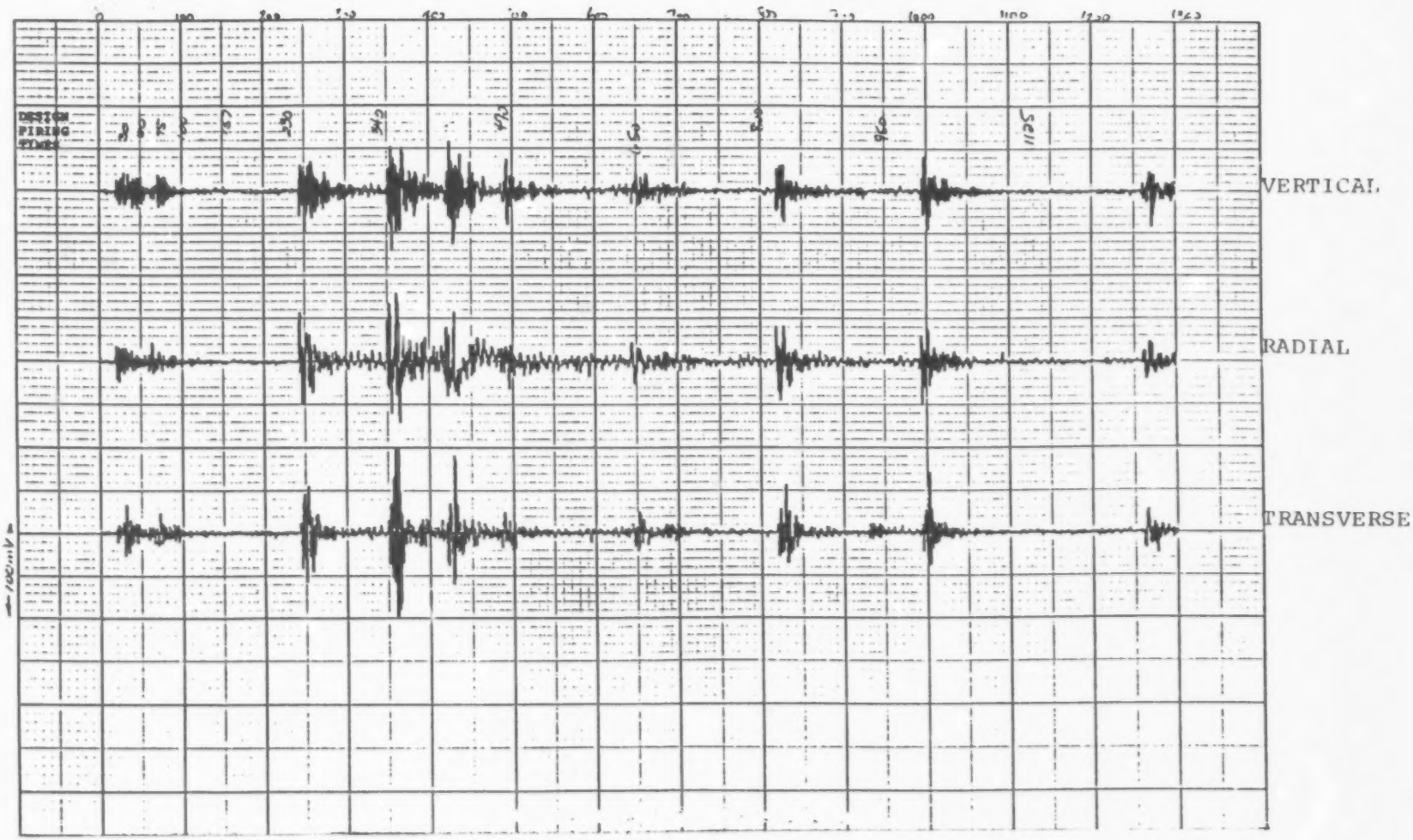


FIGURE 25C: VIBRATION TRACE, STOPE 26-150 (Stn 2 0 to 1300 ms)

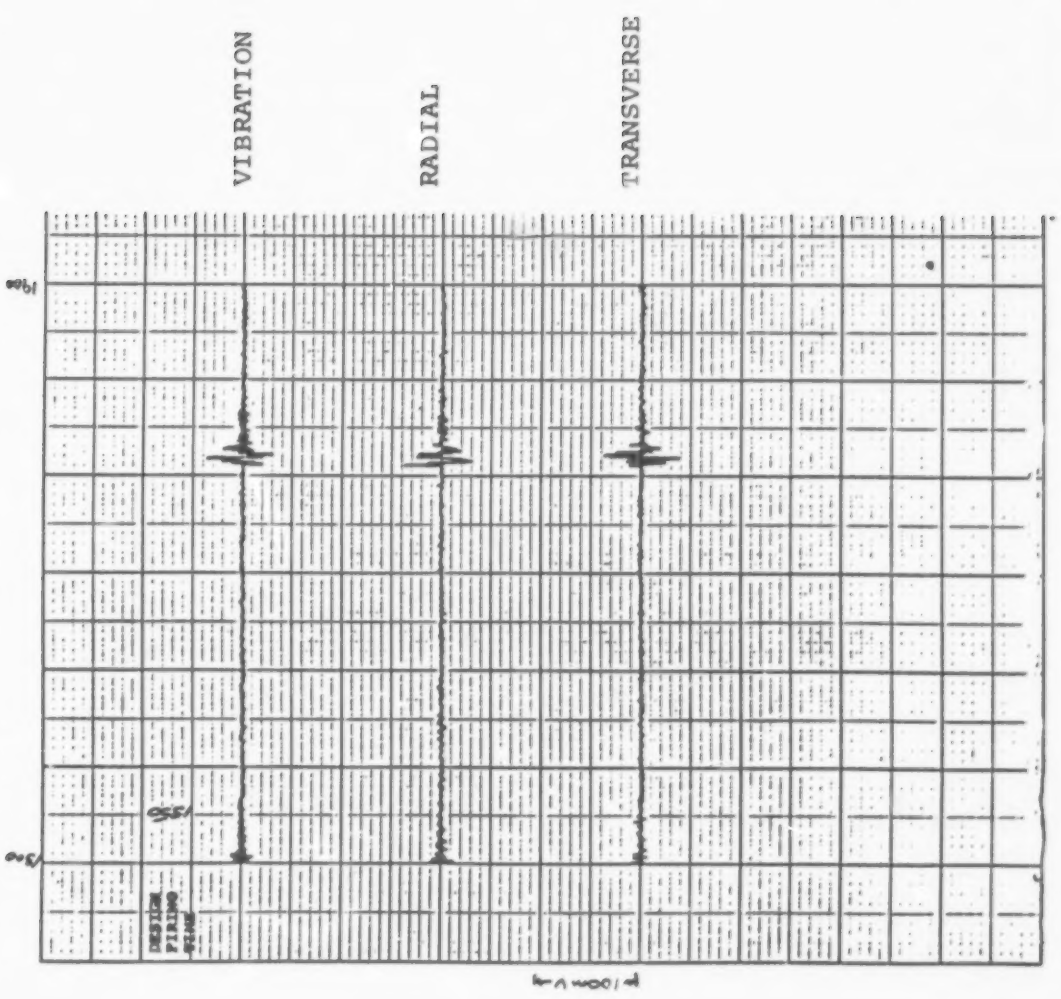


FIGURE 25D: VIBRATION TRACE, STOPE 26-150 (Stn 2 1300 to 1900 ms)

1. User specifies charge weights, location of each deck, deck separation and firing sequence.
2. Several different explosives can be used in one pattern.
3. Shallowly inclined holes are now acceptable.

A modification was also made to the bench blasting design program to allow the user to specify whether it was required to blast at the optimum of the crater curve or elsewhere. The VCR program was not modified.

5.6 Summary of Results

Five tests were completed on the bench blasting method and four on the VCR method. Vibration and fragmentation results are not available for all tests due to occasional equipment problems. All results are summarized in Tables 12, 13 and 14. A complete set of input data and results for each method is included in Appendixes A and B.

The comparisons between blast perimeter and actual breakwere reasonable with the predicted break being slightly less than the break seen in the field. This is explained by walls sloughing down after the blast. Results on the effect of borehole deviation are inconclusive for two reasons. The gyroscopic borehole monitor was unavailable during the contract and also both mining companies preferred to load each hole with a standard charge rather than changing weights for differing burdens.

BREAK PREDICTED BY VCRM PROGRAM**					
STOPE	CHARGE WEIGHT (lbs)	DEPTH OF BURIAL (ft)	SCALED DEPTH OF BURIAL ($ft/lbs^{1/3}$)	CRATER DEPTH (ft)	SCALED CRATER DEPTH ($ft/lbs^{1/3}$)
INCO					
808.6 1st lift	88	6	1.35	8.4	1.89
808.6 2nd lift	88	6	1.35	8.4	1.89
808.6 3rd lift	88	6	1.35	8.4	1.89
FALCO*					
20-134 drop raise	36	5	1.51	4.7	1.42

ACTUAL BREAK					
STOPE	CHARGE WEIGHT (lbs)	DEPTH OF BURIAL (ft)	SCALED DEPTH OF BURIAL ($ft/lbs^{1/3}$)	CRATER DEPTH (ft)	SCALED CRATER DEPTH ($ft/lbs^{1/3}$)
INCO					
808.6 1st lift	137	6	1.16	4	0.78
808.6 2nd lift	137	6	1.16	5	0.97
808.6 3rd lift	137	6	1.16	7	1.36
FALCO*					
20-134 drop raise	165	8	1.46	14	2.6

* This is not true VCR blasting because a cylindrical charge rather than a spherical charge was used in practice.
** Predicted assuming 100% efficiency.

TABLE 12: VCR BACKBREAK PER CHARGE.

STOPE LOCATION Bench Blasting:	FRAGMENTATION 50% Passing: (inches)	PREDICTED FRAGMENTATION 50% Passing: (inches)
Falco 33 - 176	19.7	15.7
Falco 20 - 134	9.8	6.3
Falco 26 - 150	11.8	10.6
Falco 27 - 165	7.5	9.8
Falco 31 - 151	13.4	11.4

TABLE 13: FRAGMENTATION PREDICTIONS.

STOPE LOCATION	PEAK PARTICLE VELOCITY		
	MEASURED (ins/sec)	PREDICTED (ins/sec)	DISTANCE (ft)
Falco 33-176*	5.3	29.9	40
Falco 20-134	16.6	10.7	78
	13.9	9.5	85
Falco 26-150	2.6	3.3	177
	3.9	4.9	110
Falco 31-151	25.9	18.3	55
	11.2	9.0	95

The discrepancy between actual and predicted peak particle velocities is in some cases due to simultaneous detonations of charges because of cap scatter.

* This calculation is based on the first two decks fired in the blast. Later decks were not properly recorded because the geophones were knocked off the wall.

TABLE 14: PEAK PARTICLE VELOCITY PREDICTIONS.

The vibration traces correspond well to predicted values. The predictions were based on the empirical formula for peak particle velocity, $V = K \left(\frac{d}{W^{1/2}}\right)^m$ described previously where:

m = -1.3 at Falconbridge

K = 57

m = -1.3 at Inco

K = 77

These site factors were determined using information from past vibration monitoring at each mine.

Fragmentation measured by the 50% passing size of blasted muck also compared well with program predictions.

6.0 CONCLUSIONS

The two programs, VCRM and LDBB have been converted to run on personal computers and have been tested in practical applications. The conversion retained all of the programs previous features except for the interactive graphics routine which would greatly slow execution.

Testing confirmed the basic theory of the blasting models and led to some structural modifications which make the program easier to use and more flexible in application. These included the ability to design an optimum blast or simulate any pattern for the bench blasting method and a choice of position on the cratering curves for both programs. A model to predict fragmentation was also added to the bench blasting program but one was not found for the VCR method.

Both programs are useful tools in blast design and are suitable for regular use in production planning. Future use will undoubtedly lead to refinement of and additions to these programs to suite each company's objectives. Falconbridge recommended the conversion of data input to a digitizer from file format which would cut data preparation time in half. Other useful developments would be a burden measuring instrument with direct data transfer to the PC, or an adaptation of the gyroscopic borehole monitor to provide automatic data input to the program. Further enhancements to this program would be the

development of a fragmentation model for VCR mining and also a thorough investigation into cratering data for underground mines in Canada.

In conclusion, the programs have performed well in testing and are ready for specific adaptation to each mine.

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1. Bauer, A., G.R. Harris, L. Lang, P. Preziosi and D.J. Selleck, "Review of Iron Ore Company's H.E. Cratering Program", Engineering and Mining Journal, September, 1965.

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4. Lang, L., "Vertical Crater Retreat: an Important New Mining Method", Underground mining Methods Handbook SME - AIME pp. 456 - 463.

5. Livingston, C.W., 1973: U.S. Patent 3,762,771, Oct. 2.

6. Roach, R., "VCR Model" CIL internal report.

APPENDIX A

TEST DATA ON PROGRAMS LDBB AND LSIM

DATA AND RESULTS FOR LDBB STOPE 20-134, LOCKERBY MINE.

20-134 STOPE HOLE COORDINATES

HOLE #	ROW	COLUMN	x(ft)	y(ft)	z(ft)
1(1)	1	1	1315.	67.5	11021
			1316.5	36.	11080
2(18x)	1	3	1324.	57.5	11021
			1325.5	17.5	11080
3(19)	1	5	1329.	50.5	11021
			1318.5	5.5	11080
4(21)	1	6	1333.	55.5	11021
			1329.5	13.	11080
5(30)	4	1	1339.	59.5	11021
			1338.	18.	11080
6(31)	1	8	1345.5	59.5	11021
			1345.5	17.5	11080
7(47)	1	10	1355.	64.	11021
			1353.	24.5	11080
8(17)	2	4	1322.5	57.	11021
			1321.	16.	11080
9(39)	2	9	1332.	109.	10932
			1335.	17.	11080
10(15)	3	2	1318.5	59.	11021
			1317.5	19.5	11080
11(17x)	3	4	1325.	61.5	11021
			1325.5	22.	11080
12(32)	3	8	1348.	64.5	11021
			1350.5	21.	11080
13(46)	3	10	1358.	73.	11021
			1361.	32.5	11080
14(2)	4	1	1315.	65.5	11021
			1316.	27.5	11080

HOLE #	ROW	COLUMN	x(ft)	y(ft)	z(ft)
15(33)	4	8	1347.5	72.	11021
			1350.	29.	11080
16(3)	5	1	1312.5	72.5	11021
			1311.5	34.	11080
17(14)	5	2	1312.5	72.5	11021
			1308.5	36.	11080

20-134 REFERENCE DATA

FALCONBRIDGE TEST 3 20-134 STOPE

1308.	00.	11021.	REFERENCE POINT,x y z (ft)
54.	75.	59.	STOPE LENGTH WIDTH DEPTH (FT)
00.			REFERENCE ANGLE (degrees)

20-134 INTERACTIVE INPUT

HOLE	SEPARATION DISTANCE BETWEEN CHARGES (ft)	WEIGHT (lbs)	EXPLOSIVE	DELAY SEQUENCE
1(1)	8	286	A	15
	6	286	A	16
2(18x)	10	286	A	7
	6	286	A	8
3(19)	6	231	NBL	18
	0	231	NBL	18
4(21)	8	231	NBL	17
	0	231	NBL	17
5(30)	9	286	A	11
	6	286	A	12
6(31)	5	231	NBL	21
	0	231	NBL	21
7(47)	7	286	A	22
	6	286	A	23
8(17)	6	286	A	13
	6	286	A	14
9(39)	3	247	NBL	24
	0	248	NBL	24
10(15)	13	286	A	9
	6	286	A	10
11(17x)	15	248	B	1
	0	247	B	1
12(32)	5	320	B	19
	6	320	B	20
13(46)	11	214	NBL	25
	0	215	NBL	25
14(2)	6	231	NBL	2
	0	231	NBL	2

HOLE	SEPARATION DISTANCE BETWEEN CHARGES (ft)	WEIGHT (lbs)	EXPLOSIVE	DELAY SEQUENCE
15(33)	4	320	B	3
	6	320	B	4
16(3)	8	231	NBL	6
	0	231	NBL	6
17(14)	14	198	NBL	5
	0	198	NBL	5

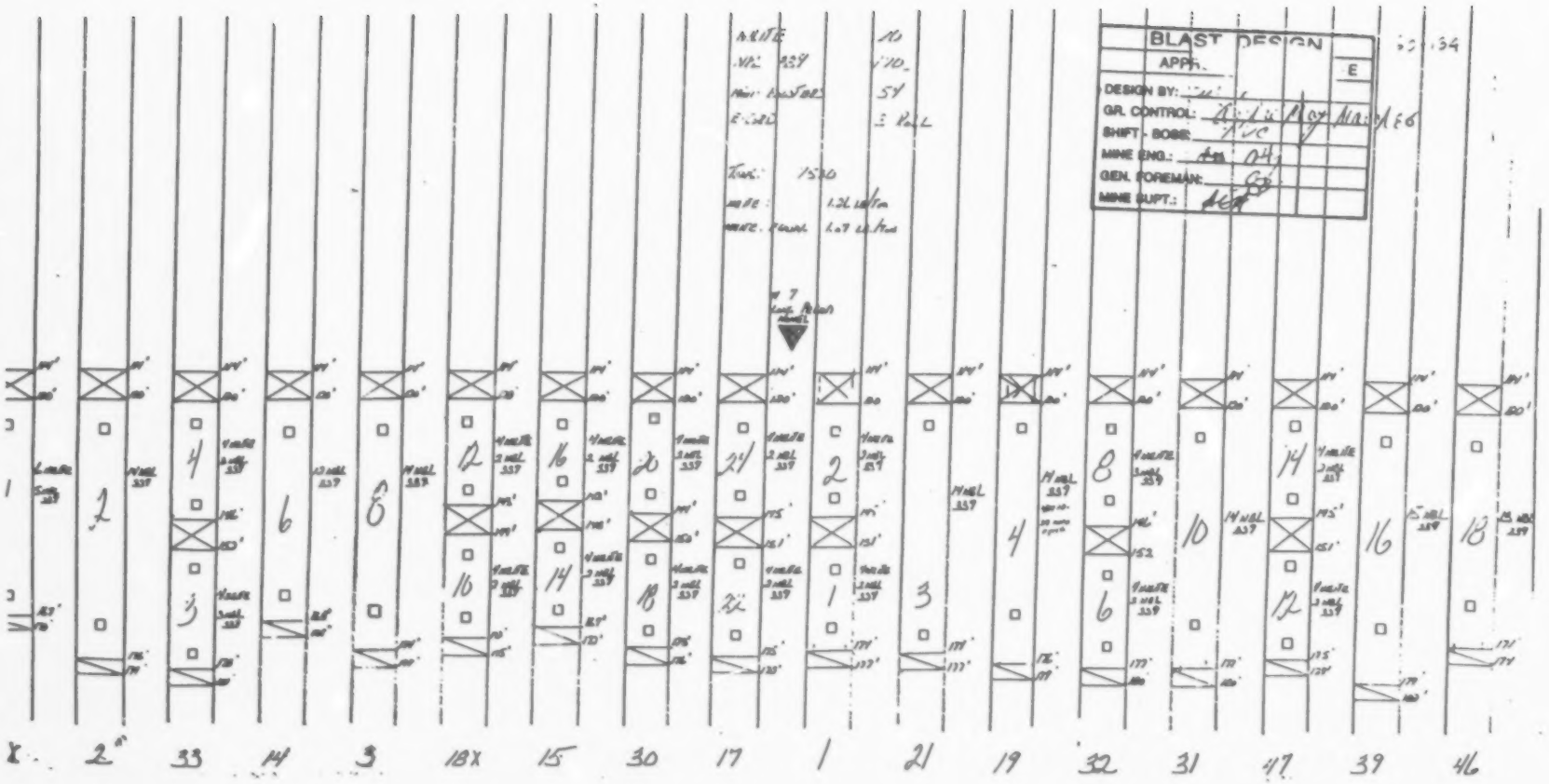
Nilite FR = N ρ = 0.031 lb/cu.in. Weight Strength = 1

NBL 339 = NBL ρ = 0.015 lb/cu.in. Weight Strength = .92

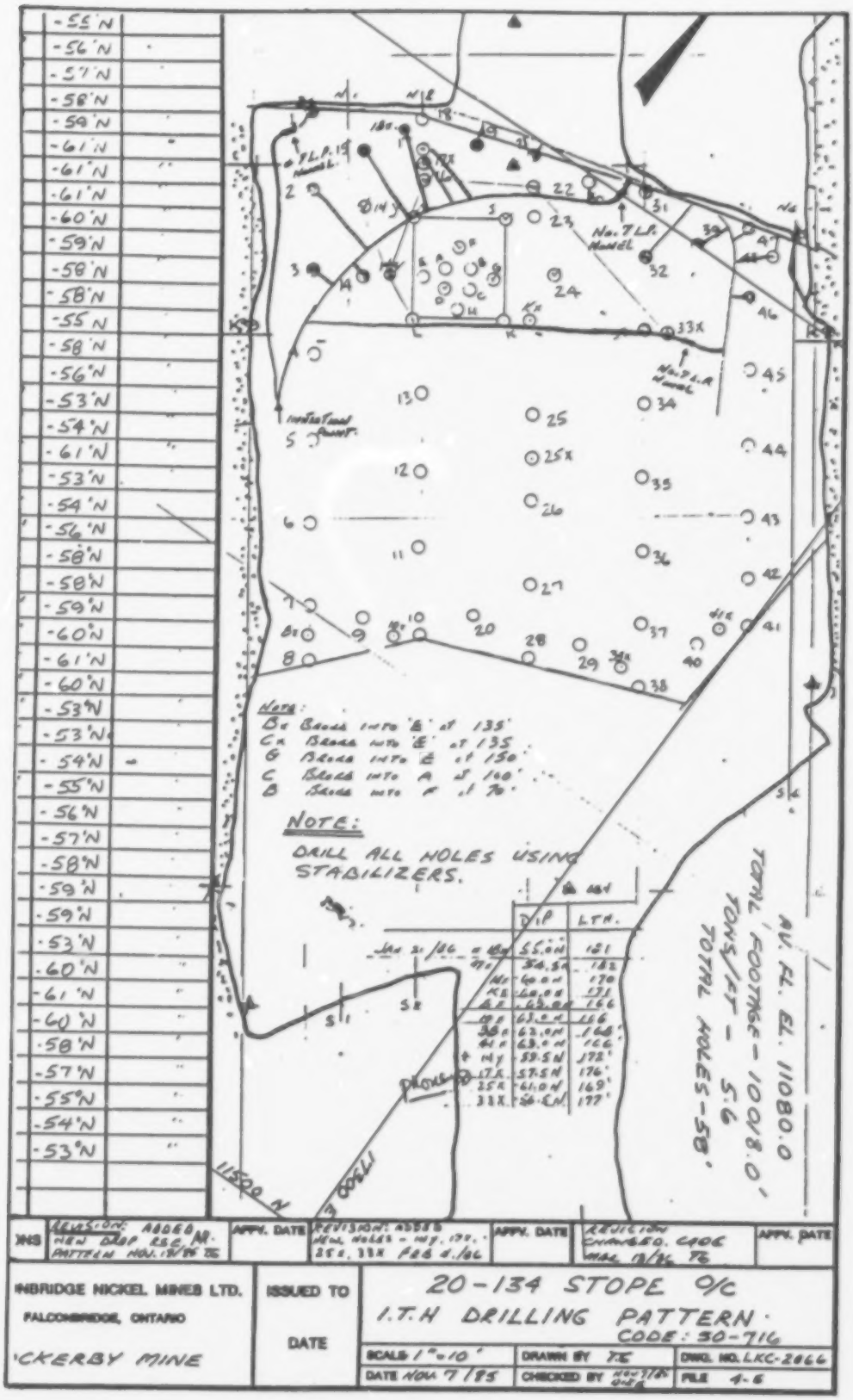
Combiinations A = 66 lbs NBL and 220 lbs Nilite
= 0.027 lb/cu.in. Weight Strength = .98
B = 165 lbs NBL and 330 lbs Nilite
= 0.026 lb/cu.in. Weight Strength = .97

Powder Factor = 1.07 lb/ton

Burden, spacing = 8 ft., 6 ft.



LOADING INSTRUCTIONS, 20-134 STOPE


-55'N
-56'N
-57'N
-58'N
-59'N
-61'N
-61'N
-61'N
-60'N
-59'N
-58'N
-58'N
-55'N
-58'N
-56'N
-53'N
-54'N
-61'N
-53'N
-54'N
-56'N
-58'N
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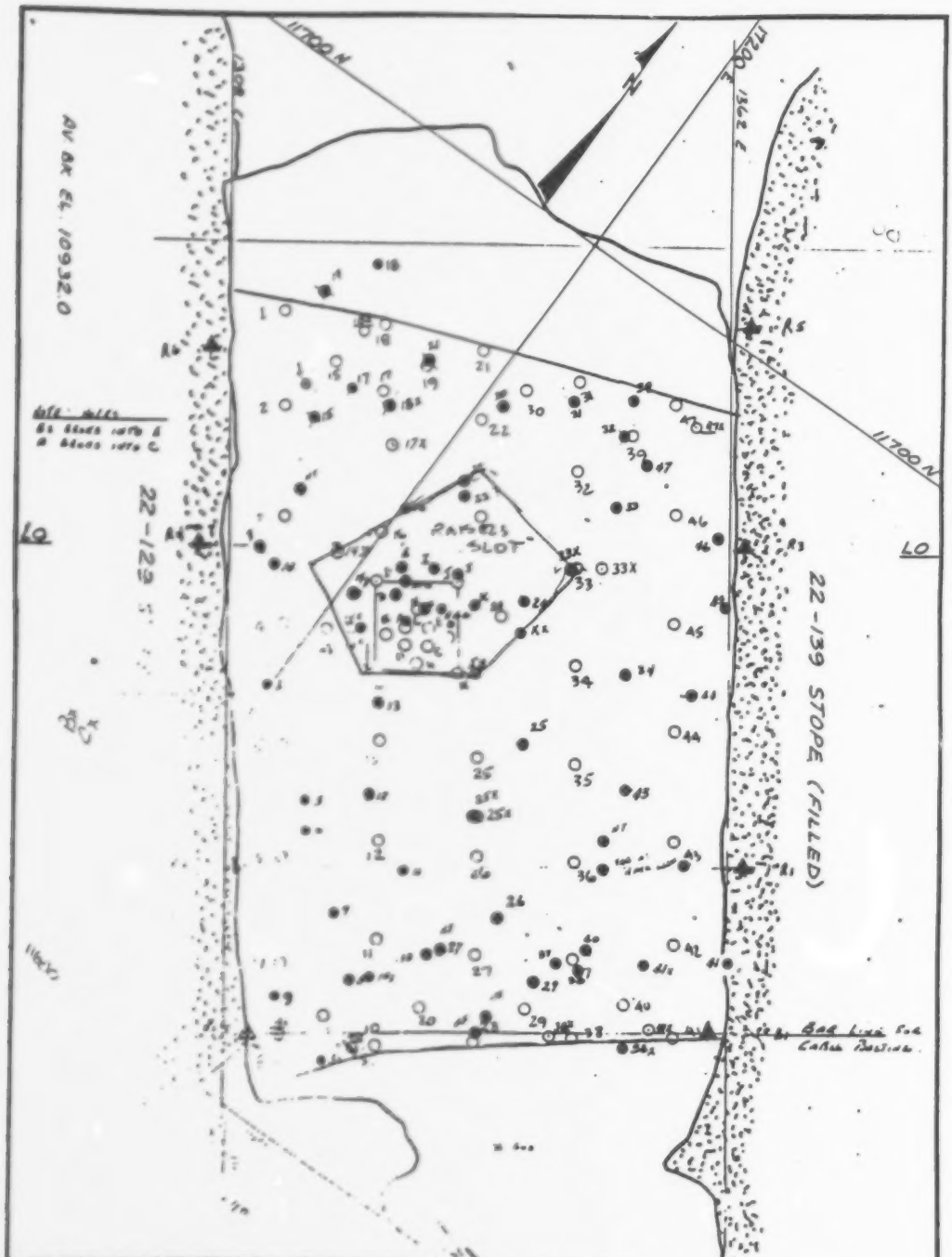
-55'N
-56'N
-57'N
-58'N
-59'N
-59'N
-53'N
-60'N
-61'N
-60'N
-58'N
-57'N
-55'N
-54'N
-53'N
Note:
B: Break into 'E' at 135'
C: Break into 'E' at 135'
G: Break into E at 150'
C: Break into A at 100'
B: Break into F at 70'
NOTE:
DRILL ALL HOLES USING STABILIZERS.
Dip
Ltn.
55.0N 121
54.5N 182
60.0N 170
60.0N 171
65.0N 166
63.0N 166
63.0N 168
63.0N 166
59.5N 172
57.5N 176
61.0N 169
56.0N 177
AV. EL. EL. 110B0.0
TOTAL FOOTAGE - 10018.0'
TONS/FT - 5.6
TOTAL HOLES-58.
11500 N
No. 7 L.H. Manuel
No. 7 L.H. Manuel
Instrument Point
DRILL
INCO
REVISION: ADDED NEW DRAFT ESC. PATTERN NOV. 18/85 DC
APPV. DATE
REVISION: ADDED NEW HOLES - HOLE 170, 25X, 33X FEB 4/86
APPV. DATE
REVISION CHANGED CODE MAR 11/86 TC
APPV. DATE
INCO
INCO
INCO



DRILLING PLAN, 20-134 STOPE UNDERCUT

PROGRAM LDBB

WRITTEN FOR THE DESIGN OF THE BLAST IN AN UNDERGROUND STOPE USING THE LARGE DIAMETER BLASTHOLE BENCHING METHOD.

EXPLOSIVE USED: NBL
DENSITY: 0.0150 LBS/CUBIC INCH
DIAMETER: 6.5000 INCH

INITIATION SEQUENCE IN LEVEL #1

HOLE NUMBER	DELAY PERIOD
1	15
2	7
3	28
4	17
5	11
6	21
7	22
8	13
9	24
10	9
11	1
12	19
13	25
14	2
15	3
16	6
17	5

WEIGHT OF EXPLOSIVE DECKS IN LEVEL #1

HOLE NUMBER	WEIGHT (LBS)	EXPLOSIVE TYPE
1	286.	A
2	286.	A
3	231.	NBL
4	231.	NBL
5	286.	A
6	231.	NBL
7	286.	A
8	286.	A
9	247.	NBL
10	286.	A
11	248.	B
12	320.	B
13	214.	NBL
14	231.	NBL
15	320.	B
16	231.	NBL
17	198.	NBL

A = 10:3 Nilite:NBL (by weight)

B = 2:1 Nilite:NBL (by weight)

NBL = NBL339 (low density ANFO)

1 PLAN VIEW AT DEPTH 60.0000

INITIATION SEQUENCE IN LEVEL #2

HOLE NUMBER	DELAY PERIOD
1	16
2	8
3	19
4	18
5	12
6	23
7	25
8	14
9	26
10	10
11	2
12	23
13	28
14	3
15	5
16	7
17	6

WEIGHT OF EXPLOSIVE DECKS IN LEVEL #2

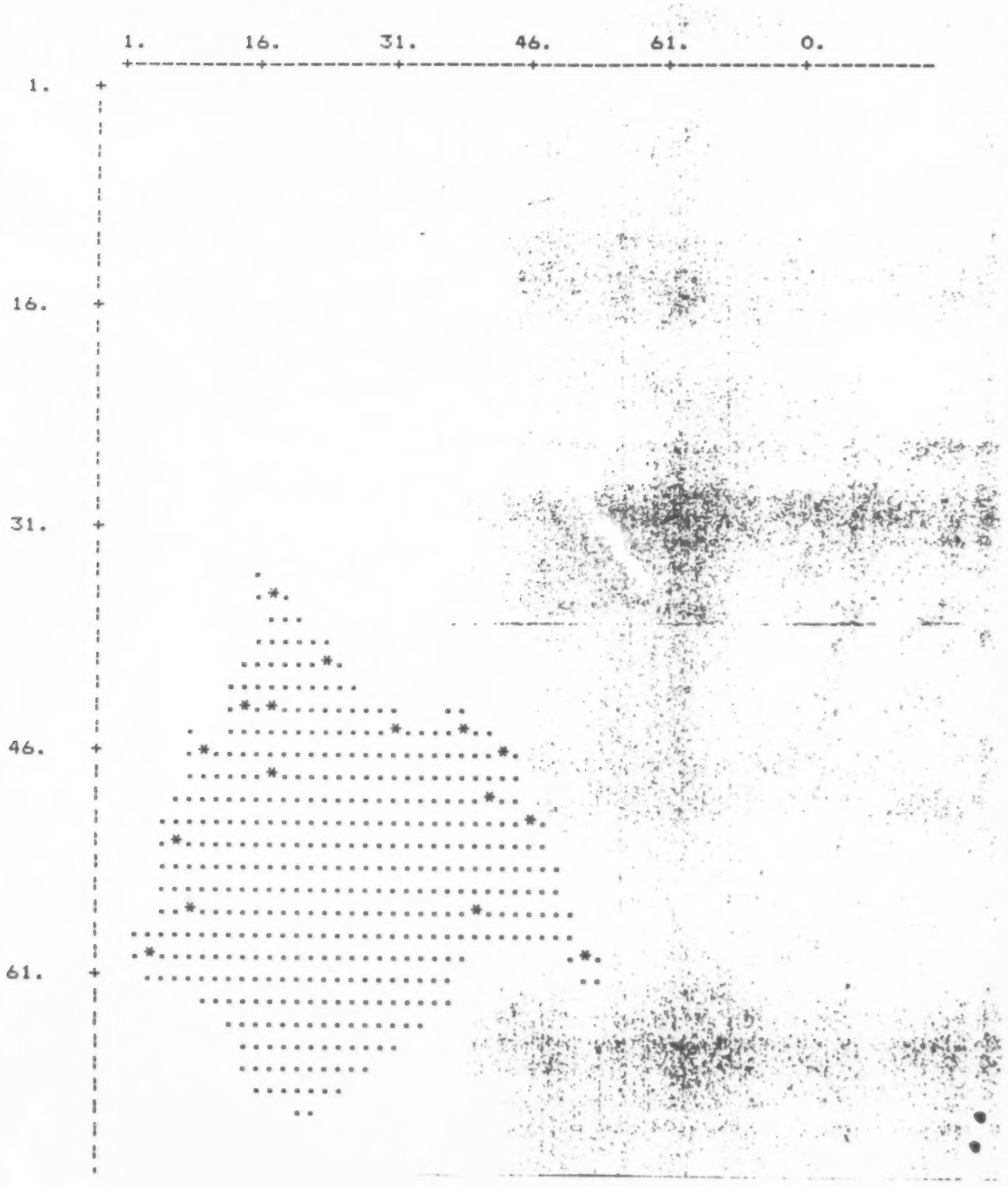
HOLE NUMBER	WEIGHT (LBS)	EXPLOSIVE TYPE
1	286.	A
2	286.	A
3	231.	NBL
4	231.	NBL
5	286.	A
6	231.	NBL
7	286.	A
8	286.	A
9	248.	NBL
10	286.	A
11	247.	B
12	320.	B
13	215.	NBL
14	231.	NBL
15	320.	B
16	231.	NBL
17	198.	NBL

A = 10:3 Nilite:NBL (by weight)

B = 2:1 Nilite:NBL (by weight)

NBL = NBL339 (low density ANFO)

PLAN VIEW AT DEPTH 27.3986



SUMMARY

TOTAL WEIGHT OF EXPLOSIVE: 8837. LBS

DELAY NUMBER	QUANTITY
1	1
2	2
3	2
4	0
5	2
6	2
7	2
8	1
9	1
10	1
11	1
12	1
13	1
14	1
15	1
16	1
17	1
18	2
19	2
20	0

DELAY NUMBER	QUANTITY
21	1
22	1
23	2
24	1
25	2
26	1
27	0
28	1

INSTRUCTIONS FOR LOADING

HOLE NUMBER	CHARGE LOCATION DISTANCE TO BOTTOM CHARGE (ft)	CHARGE WEIGHT (lbs)	DELAY NUMBER	EXPLOSIVE TYPE
1	66.	286.	15	A
	29.	286.	16	A
2	67.	286.	7	A
	28.	286.	8	A
3	74.	231.	18	NBL
	24.	231.	19	NBL
4	70.	231.	17	NBL
	22.	231.	18	NBL
5	69.	286.	11	A
	29.	286.	12	A
6	73.	231.	21	NBL
	25.	231.	23	NBL
7	71.	286.	22	A
	31.	286.	25	A
8	71.	286.	13	A
	32.	286.	14	A
9	76.	247.	24	NBL
	24.	248.	26	NBL
10	63.	286.	9	A
	24.	286.	10	A
11	61.	248.	1	B
	33.	247.	2	B
12	75.	320.	19	B
	29.	320.	23	B
13	65.	214.	25	NBL
	22.	215.	28	NBL
14	70.	231.	2	NBL
	24.	231.	3	NBL

HOLE NUMBER	CHARGE LOCATION DISTANCE TO BOTTOM CHARGE (ft)	CHARGE WEIGHT (lbs)	DELAY NUMBER	EXPLOSIVE TYPE
15	76.	320.	3	B
	30.	320.	5	B
16	68.	231.	6	NBL
	22.	231.	7	NBL
17	61.	198.	5	NBL
	22.	198.	6	NBL

PREDICTED FRAGMENTATION

80.00 PERCENT PASSING SIZE = 10.9 INCHES

70.00 PERCENT PASSING SIZE = 9.0 INCHES

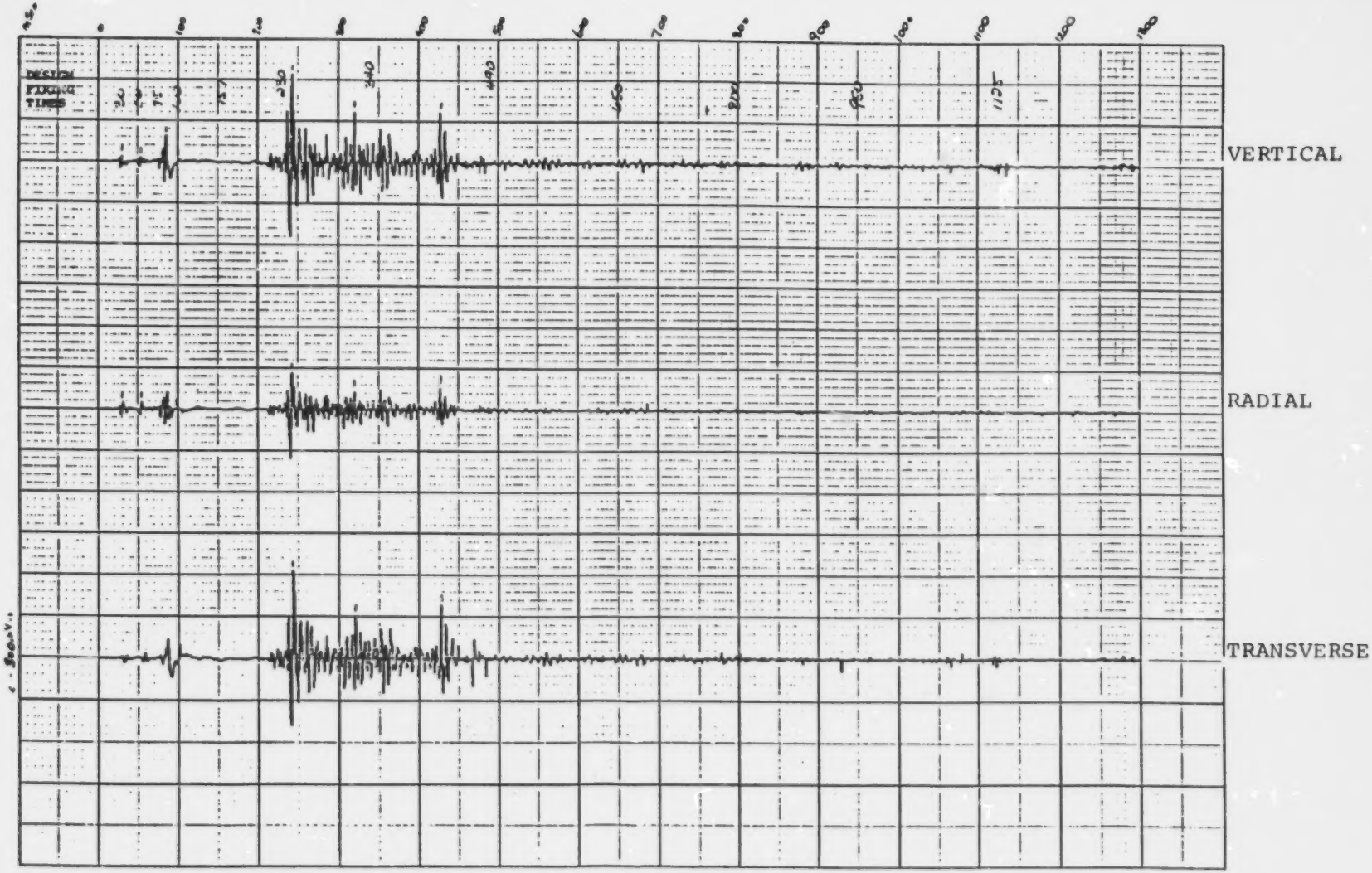
60.00 PERCENT PASSING SIZE = 7.6 INCHES

50.00 PERCENT PASSING SIZE = 6.4 INCHES

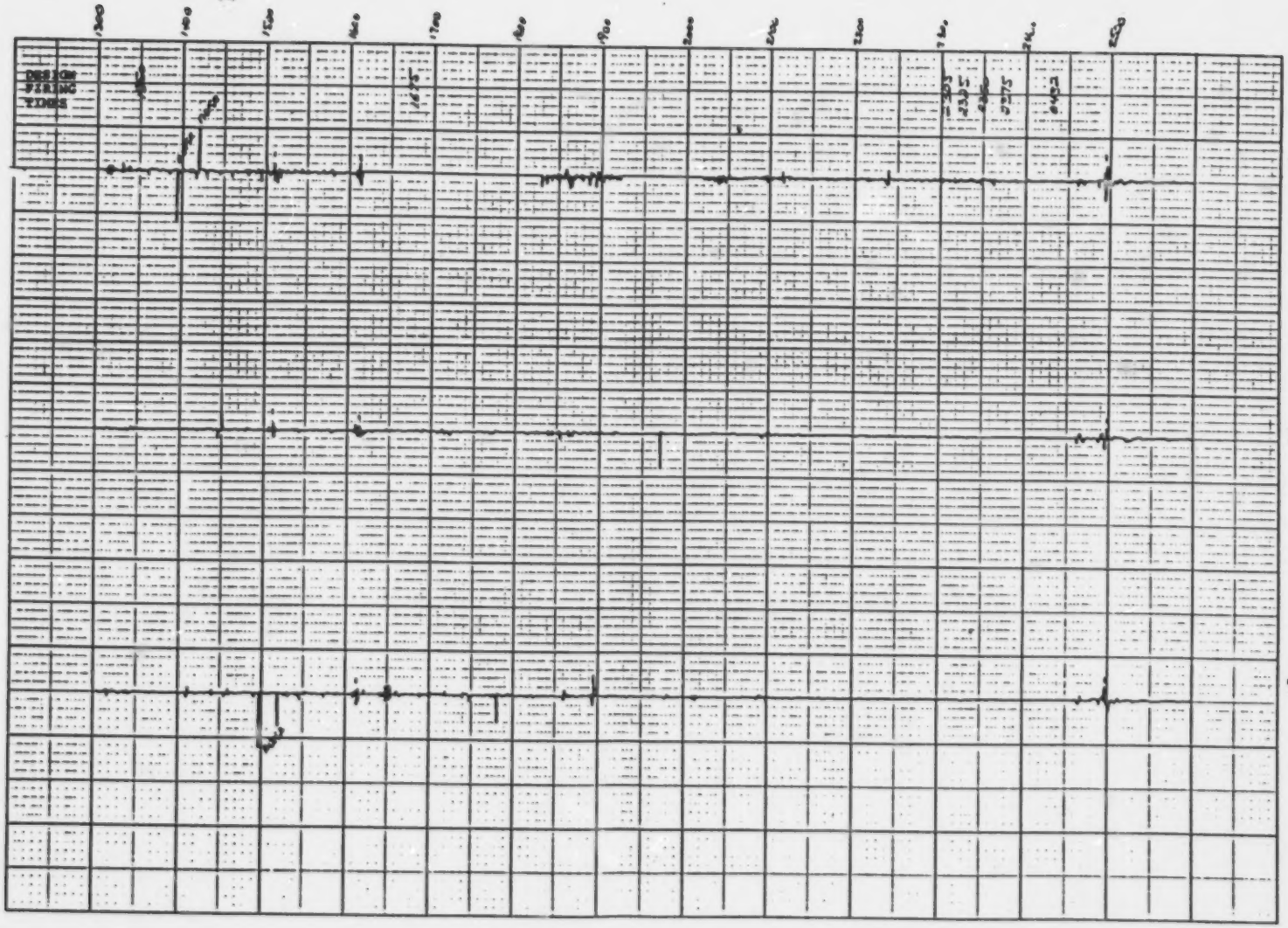
40.00 PERCENT PASSING SIZE = 5.3 INCHES

30.00 PERCENT PASSING SIZE = 4.2 INCHES

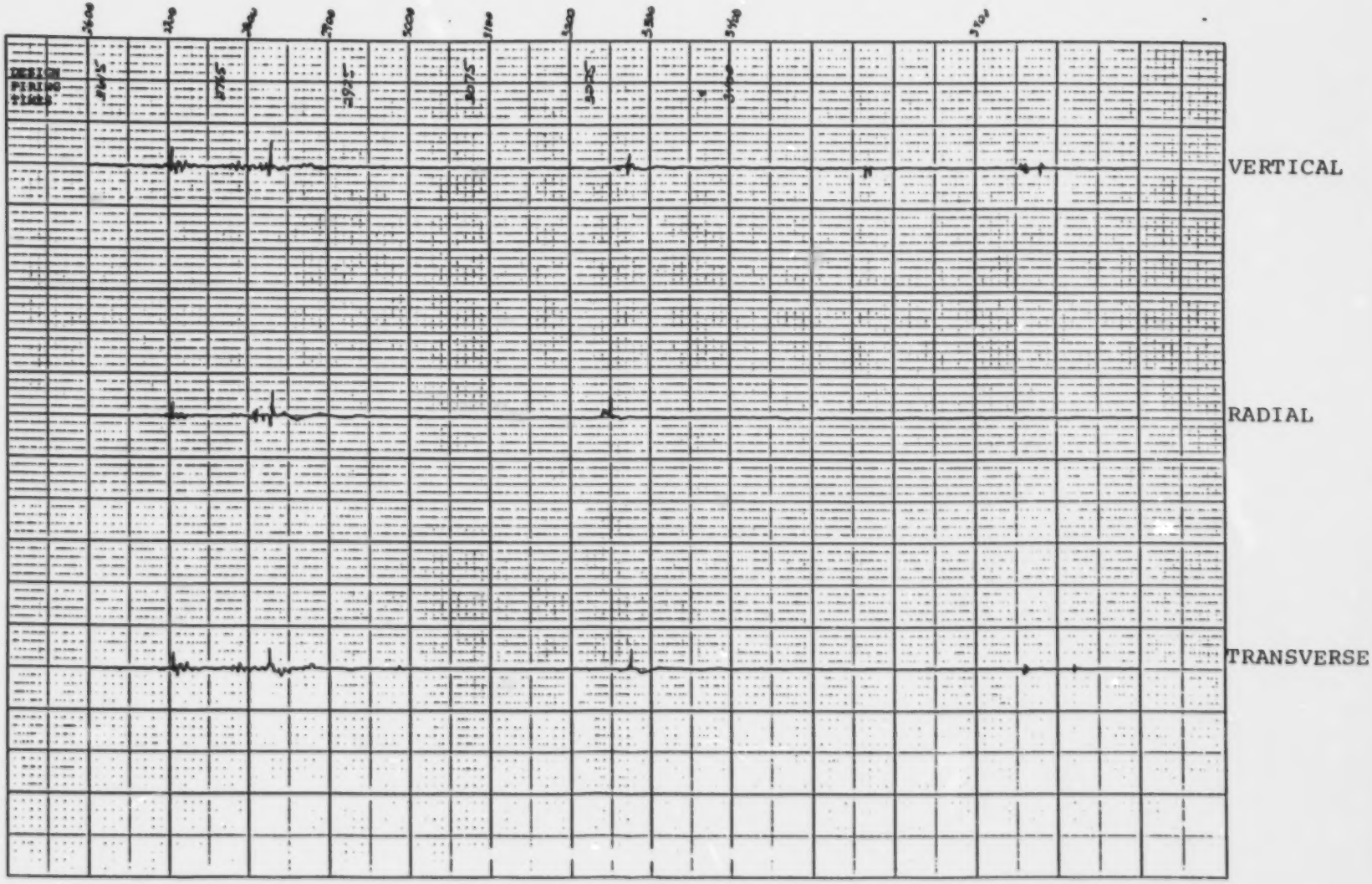
20.00 PERCENT PASSING SIZE = 3.1 INCHES



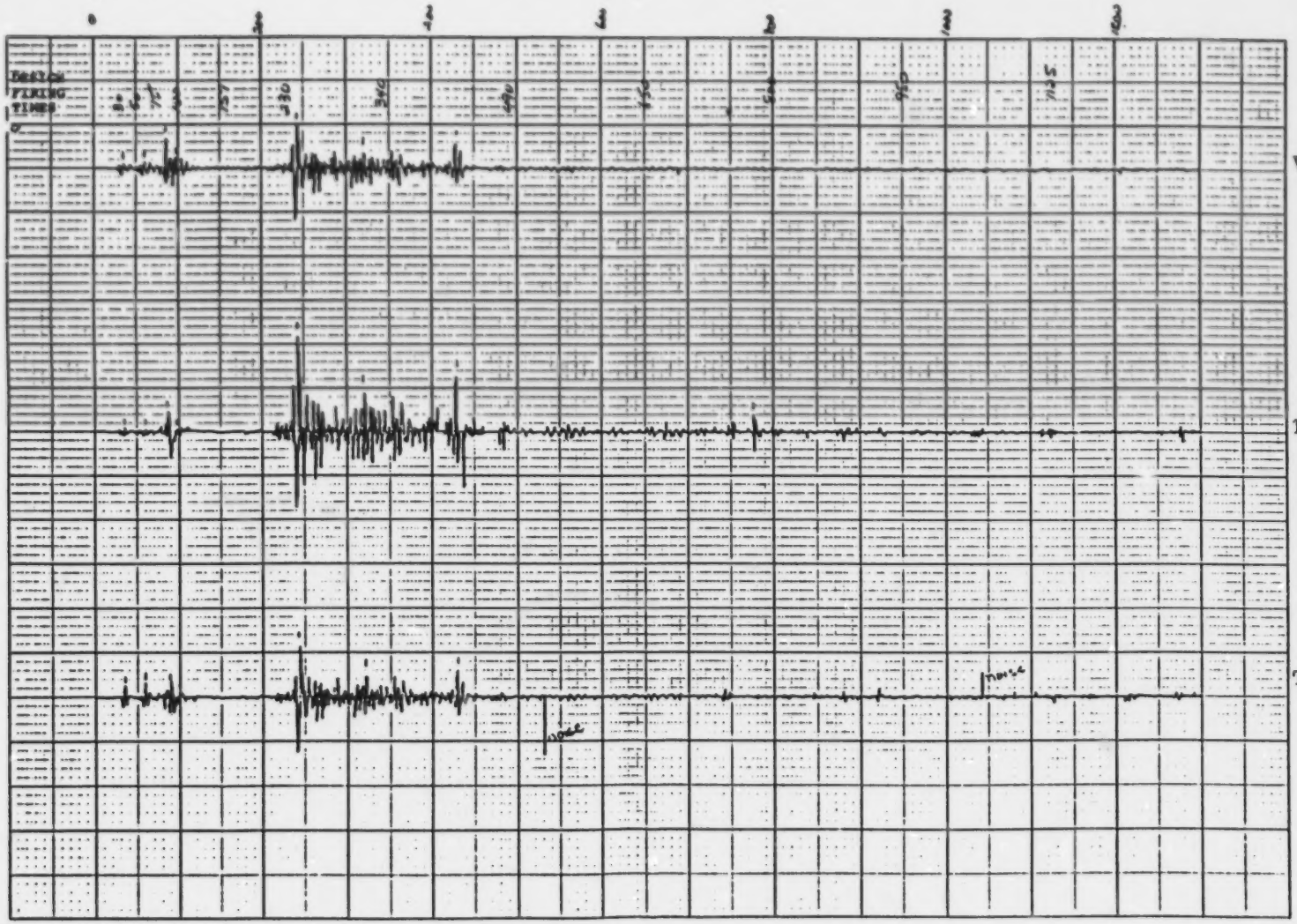
VIBRATION TRACES, 20-134 STOPE (Stn 1, 0 TO 1300 ms)



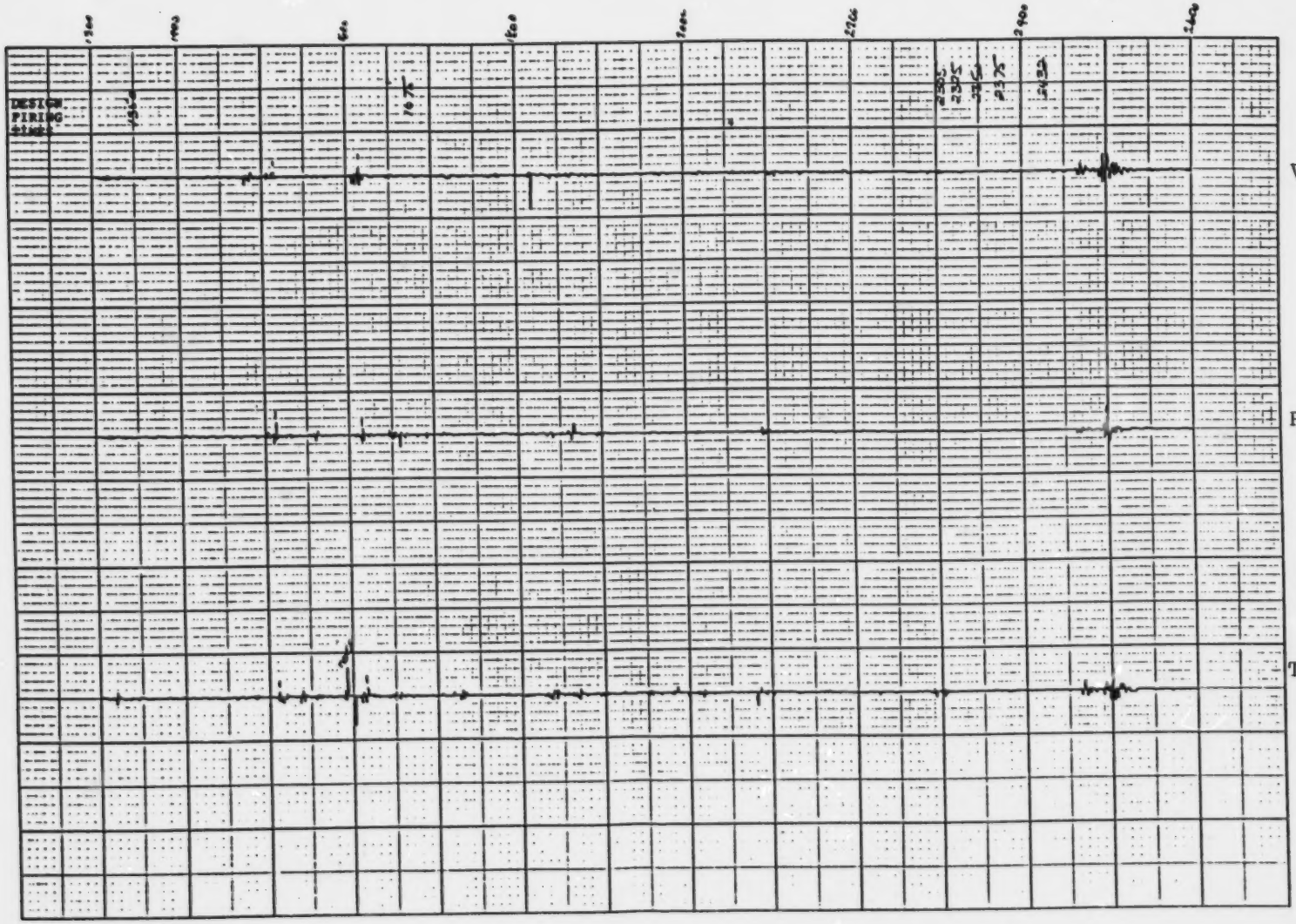
VIBRATION TRACES, 20-134 STOPE (Stn 1, 1300 to 2600 ms)



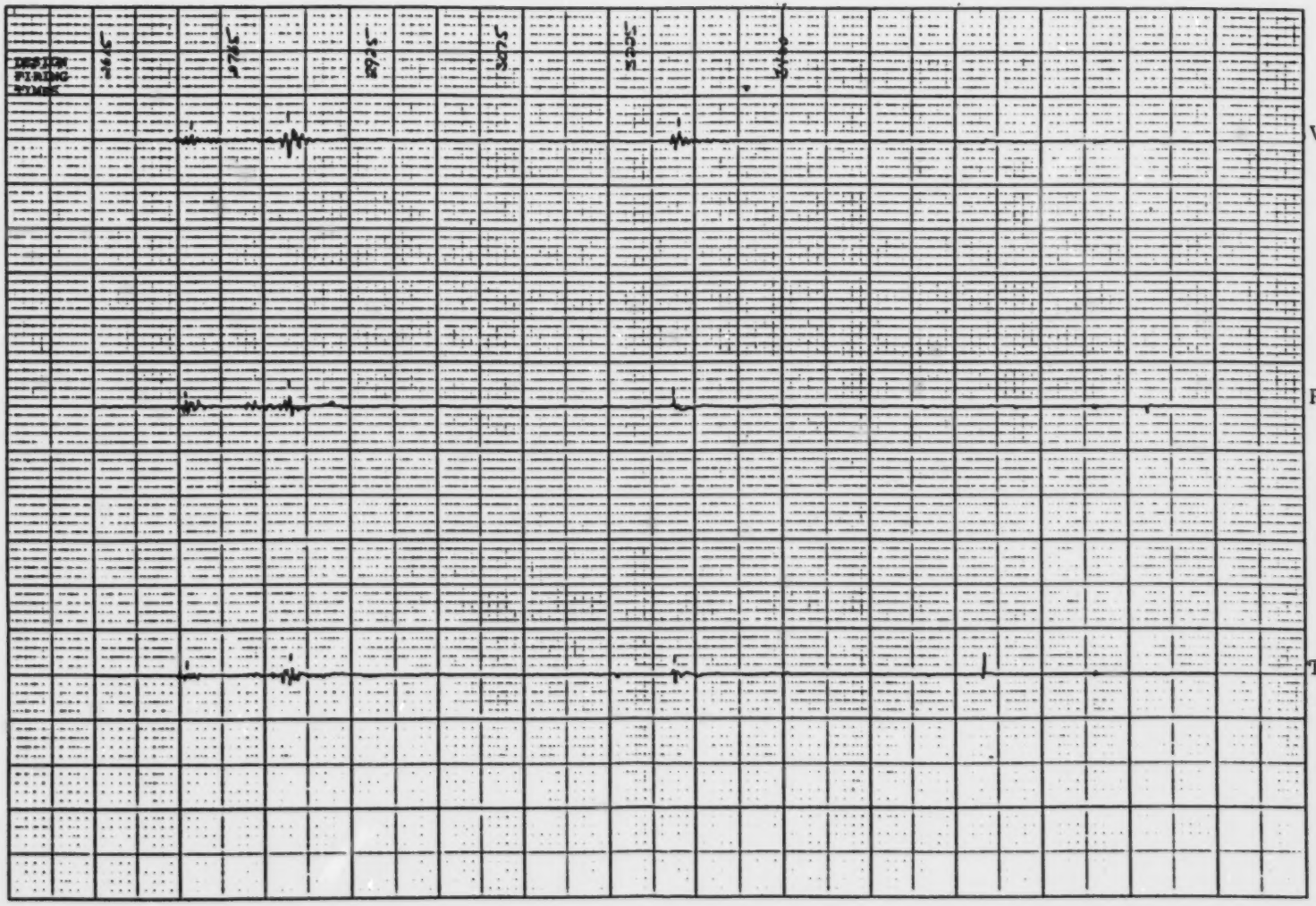
VIBRATION TRACES, 20-134 STOPE (Stn 1, 2600 to 3900 ms)



VIBRATION TRACE, 20-134 STOPE (Stn 2, 0 to 1300 ms)



VIBRATION TRACES, 20-134 STOPE (Stn 2, 1300 to 2600 ms)



VIBRATION TRACES, 20-134 STOPE (Stn 2, 2600 to 3900 ms)

DATA AND RESULTS FOR LDBB STOPE 31-151, LOCKERBY MINE

31-151 HOLE COORDINATES

HOLE #	ROW	COLUMN	x(ft)	y(ft)	z(ft)
1(6)	1	1	1491	12.5	9897
			1494	23	10091
2(28)	1	5	1521	20	9897
			1519	18	10091
3(7)	2	1	1492	21	9897
			1497	24	10091
4(9)	2	2	1500	24	9897
			1504	25	10091
5(23)	2	3	1512	26	9897
			1511	25	10091
6(27)	2	5	1521	29	9897
			1518	23	10091
7(8x)	3	1	1497	28	9897
			1501	24	10091
8(24)	3	2	1506	33	9897
			1508	30	10091
9(25)	3	3	1512	33	9897
			1517	28	10091
10(25x)	3	4	1514	34	9897
			1516	34	10091
11(26)	3	5	1518	33	9897
			1521	29	10091

31-151 SLOT OUTLINE

	x(ft)	y(ft)	z(ft)
1	1488	0	9897
	1488	0	10091
2	1488	5	9897
	1490	15	10091
3	1506	14	9897
	1506	20	10091
4	1516	16	9897
	1516	20	10091
5	1524	10	9897
	1524	15	10091
6	1524	0	9897
	1524	0	10091

- see users manual for description of slot outline data development.

31-151 REFERENCE DATA

0	1488	9897	REFERENCE POINT, x y z (ft)
50	50	195	STOPE WIDTH, LENGTH DEPTH (ft)
0			REFERENCE ANGLE (degrees)

Nilite = N ρ = 0.031 lb/cu.in. Weight Strength = 1

NBL = NBL ρ = 0.015 lb/cu.in. Weight Strength = 0.92

Powder Factor = $\frac{11{,}110 \text{ lbs}}{13{,}070 \text{ tons}}$ = 0.85 lbs/ton

31-151 INTERACTIVE INPUT

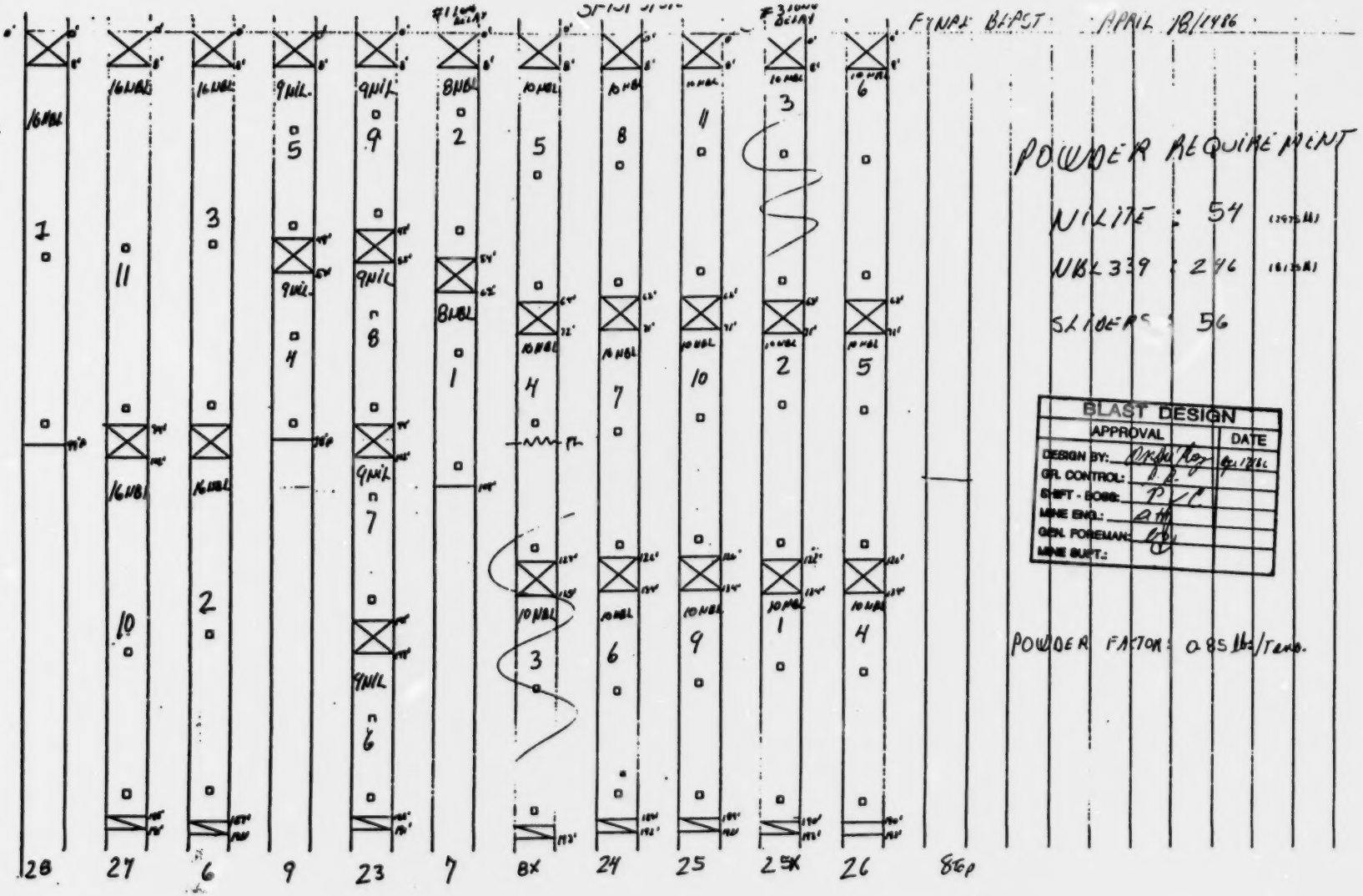
HOLE #	SEPARATION DISTANCE BETWEEN DECKS (ft)	WEIGHT (lbs)	EXPLOSIVE	DELAY SEQUENCE
LEVEL 1				
1	3	264	NBL	2
2	3	0	NBL	1
3	3	0	NBL	12
4	3	0	N	4
5	5	495	N	6
6	5	264	NBL	10
7	3	0	NBL	15
8	4	330	NBL	17
9	4	330	NBL	20
10	3	330	NBL	23
11	3	330	NBL	26
LEVEL 2				
1	0	264	NBL	2
2	0	0	NBL	1
3	0	0	NBL	12
4	0	0	N	4
5	8	495	N	7
6	0	264	NBL	10

HOLE #	SEPARATION DISTANCE BETWEEN DECKS (ft)	WEIGHT (lbs)	EXPLOSIVE	DELAY SEQUENCE
7	0	0	NBL	15
8	8	165	NBL	18
9	8	165	NBL	21
10	8	165	NBL	24
11	8	165	NBL	27
LEVEL 3				
1	8	264	NBL	3
2	0	264	NBL	1
3	0	264	NBL	12
4	0	495	N	4
5	8	495	N	8
6	8	264	NBL	11
7	0	330	NBL	15
8	0	165	NBL	18
9	0	165	NBL	21
10	0	165	NBL	24
11	0	165	NBL	27
LEVEL 4				
1	0	264	NBL	3
2	0	264	NBL	1

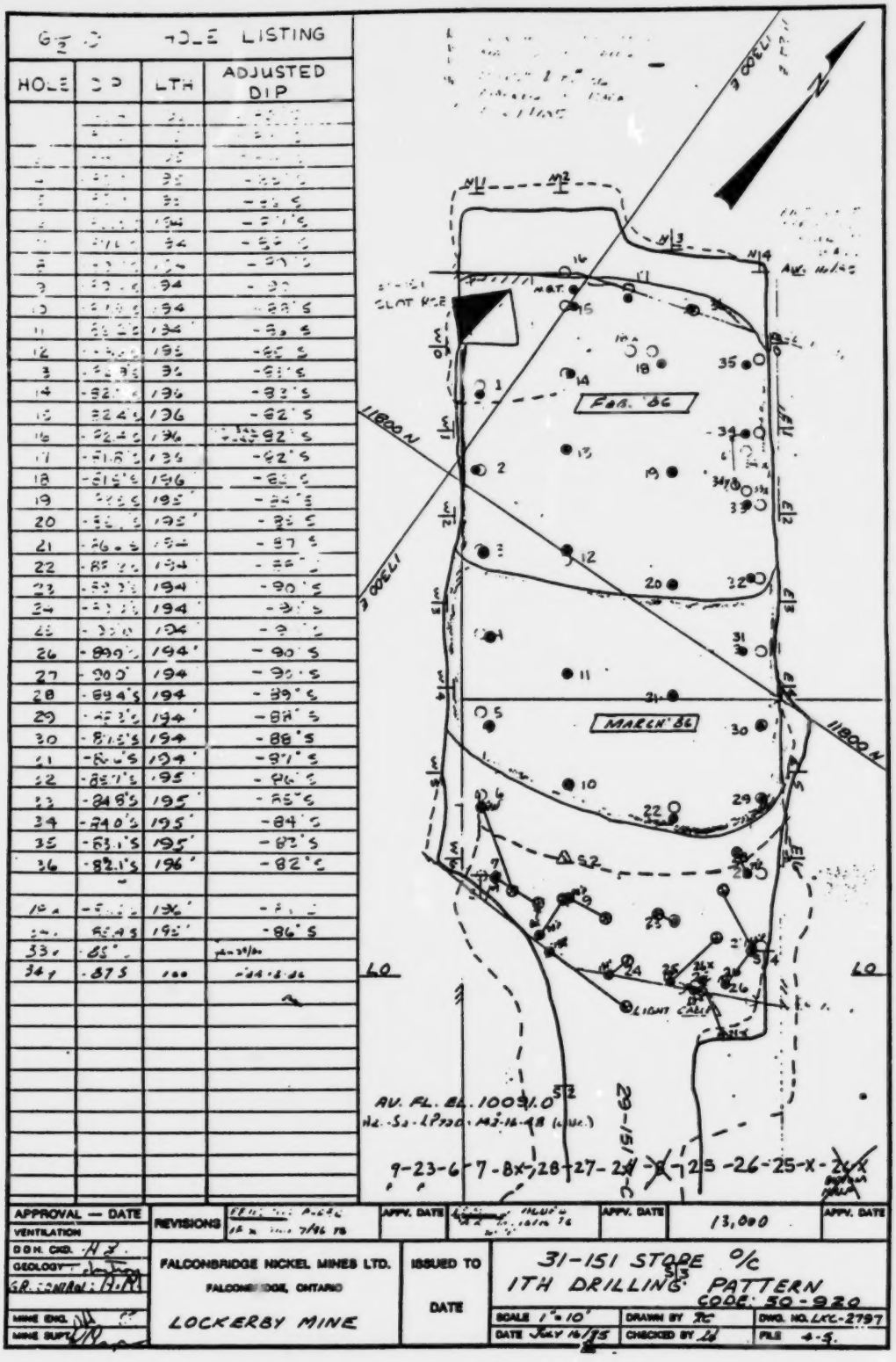
HOLE #	SEPARATION DISTANCE BETWEEN DECKS (ft)	WEIGHT (lbs)	EXPLOSIVE	DELAY SEQUENCE
3	8	264	NBL	13
4	8	495	N	5
5	8	495	N	9
6	0	264	NBL	11
7	0	330	NBL	19
9	8	330	NBL	22
10	8	0	NBL	25
11	8	330	NBL	28

N = Nilite FR (ANFO)

NBL = NBL339 (low density ANFO)

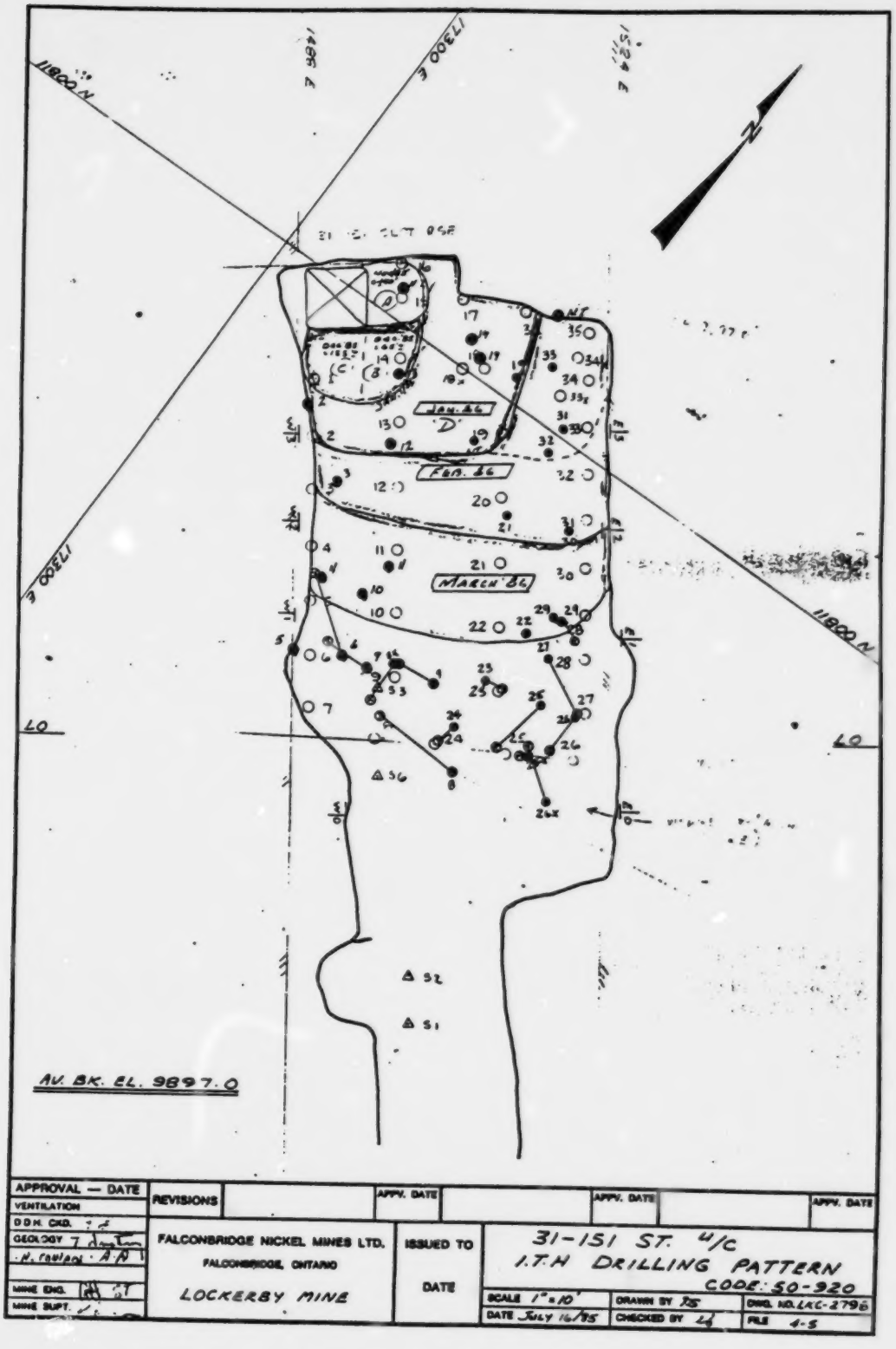


LOADING INSTRUCTIONS, 31-151 STOPE



G-T-D HOLE LISTING

HOLE	DIP	LTH	ADJUSTED DIP
		32	
		32	
		194	
		32	
		194	
		194	
		194



DRILLING PLAN, 31-151 UNDERCUT

FALCONBRIDGE - 31-151 STOPE

PROGRAM LDBB

WRITTEN FOR THE DESIGN OF THE BLAST IN AN UNDERGROUND STOPE USING THE LARGE DIAMETER BLASTHOLE BENCHING METHOD.

EXPLOSIVE USED: NBL
DENSITY: 0.0150 LBS/CUBIC INCH
DIAMETER: 6.5000 INCH

INITIATION SEQUENCE IN LEVEL #1

HOLE NUMBER	DELAY PERIOD
1	2
2	1
3	12
4	4
5	6
6	10
7	15
8	17
9	20
10	23
11	26

WEIGHT OF EXPLOSIVE DECKS IN LEVEL #1

HOLE NUMBER	WEIGHT (LBS)	EXPLOSIVE TYPE
1	264.	NBL
2	0.	NBL
3	0.	NBL
4	0.	N
5	495.	N
6	264.	NBL
7	0.	NBL
8	330.	NBL
9	330.	NBL
10	330.	NBL
11	330.	NBL

N = Nilite (ANFO)

NBL = NBL339 (low density ANFO)

33.
0.
33.

INITIATION SEQUENCE IN LEVEL #2

HOLE NUMBER	DELAY PERIOD
1	3
2	2
3	14
4	6
5	9
6	12
7	17
8	20
9	23
10	26
11	29

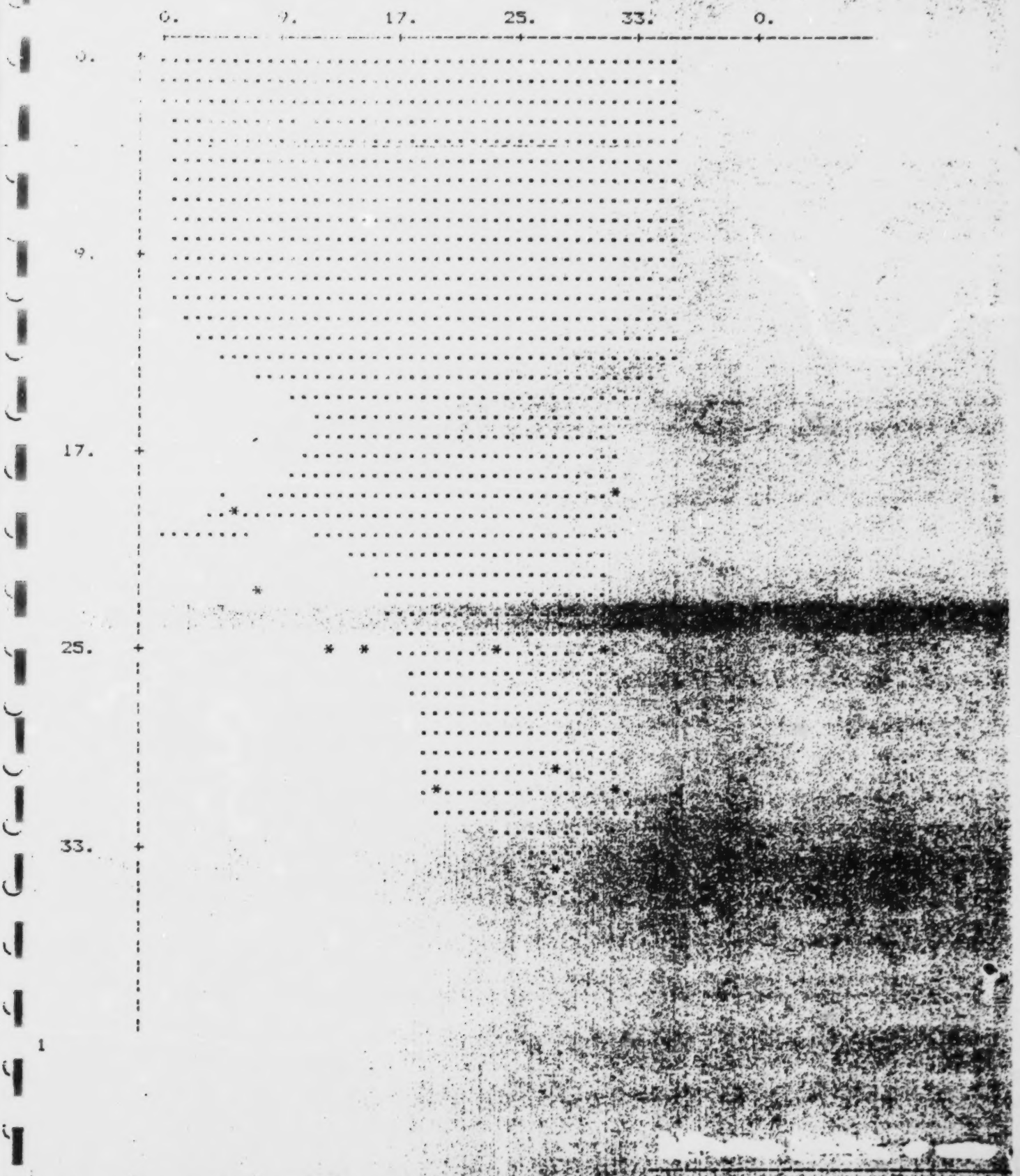
WEIGHT OF EXPLOSIVE DECKS IN LEVEL #2

HOLE NUMBER	WEIGHT (LBS)	EXPLOSIVE TYPE
1	264.	NBL
2	0.	NBL
3	0.	NBL
4	0.	N
5	495.	N
6	264.	NBL
7	0.	NBL
8	165.	NBL
9	165.	NBL
10	165.	NBL
11	165.	NBL

N = Nilite FR (ANFO)

NBL = NBL339 (low density ANFO)

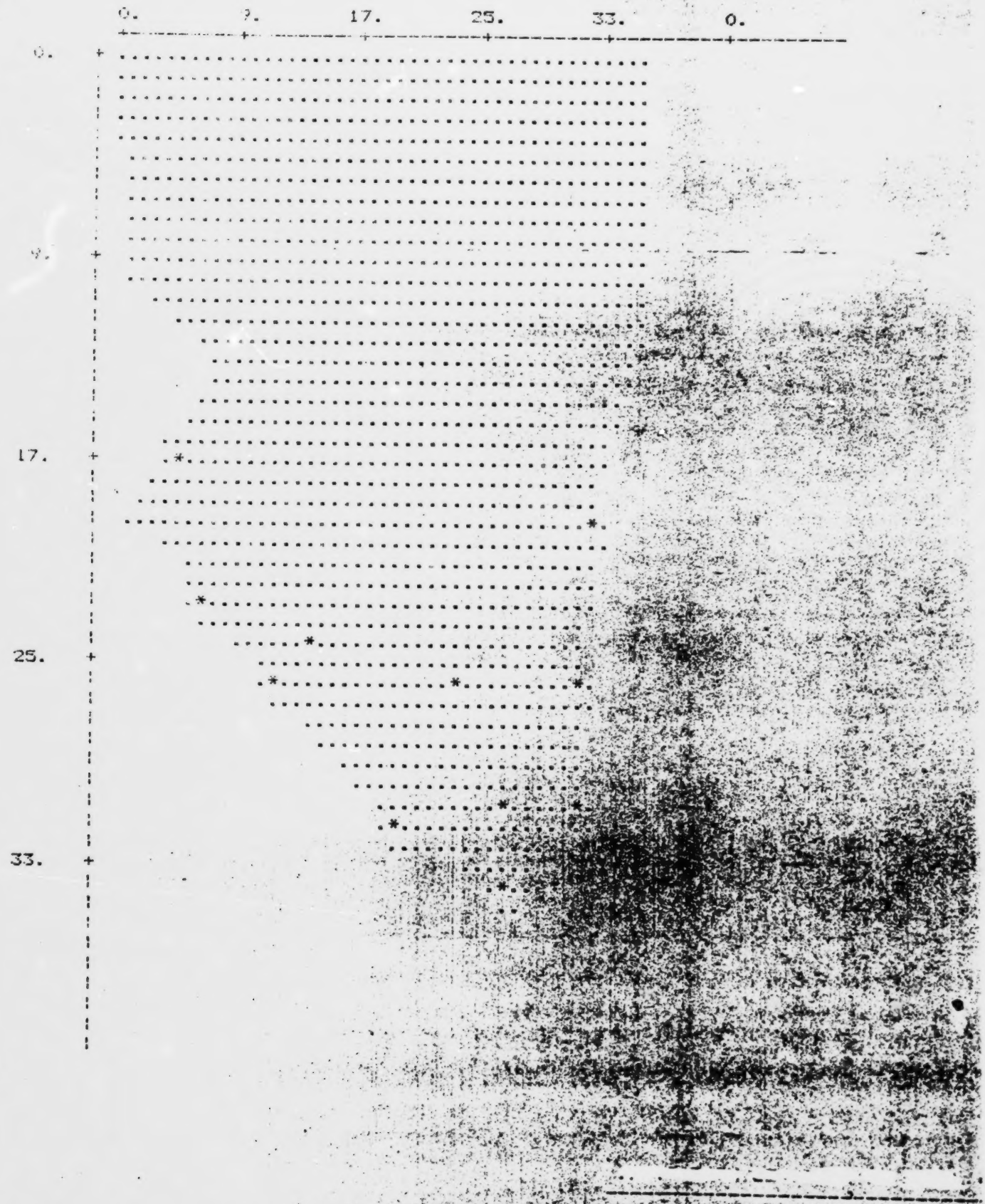
PLAN VIEW AT DEPTH 145.8007



INITIATION SEQUENCE IN LEVEL #3

HOLE NUMBER	DELAY PERIOD
1	4
2	3
3	15
4	7
5	11
6	14
7	18
8	21
9	24
10	27
11	30

PLAN VIEW AT DEPTH 75.8014



WEIGHT OF EXPLOSIVE DECKS IN LEVEL #3

HOLE NUMBER	WEIGHT (LBS)	EXPLOSIVE TYPE
1	264.	NBL
2	264.	NBL
3	264.	NBL
4	495.	N
5	495.	N
6	264.	NBL
7	330.	NBL
8	165.	NBL
9	165.	NBL
10	165.	NBL
11	165.	NBL

N = Nilite FR (ANFO)

NBL = NBL339 (low density ANFO)

INITIATION SEQUENCE IN LEVEL #4

HOLE NUMBER	DELAY PERIOD
1	5
2	4
3	18
4	10
5	14
6	16
7	21
8	24
9	27
10	30
11	33

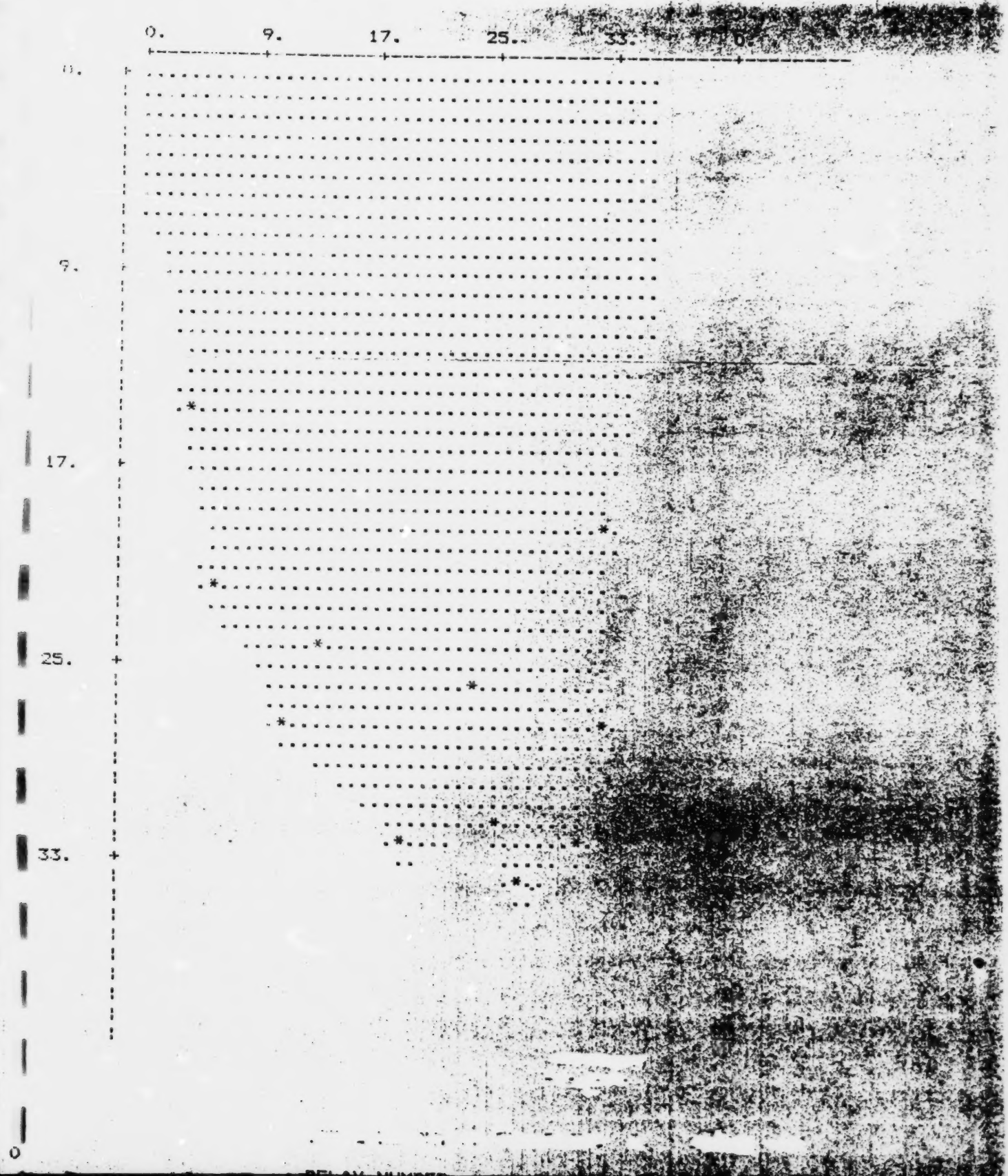
WEIGHT OF EXPLOSIVE DECKS IN LEVEL #4

HOLE NUMBER	WEIGHT (LBS)	EXPLOSIVE TYPE
1	264.	NBL
2	264.	NBL
3	264.	NBL
4	495.	N
5	495.	N
6	264.	NBL
7	330.	NBL
8	330.	NBL
9	330.	NBL
10	0.	NBL
11	330.	NBL

N = Nilite FR (ANFO)

NBL = NBL339 (low density ANFO)

PLAN VIEW AT DEPTH 49.4022



SUMMARY

TOTAL WEIGHT OF EXPLOSIVE: 10428. LBS

DELAY NUMBER	QUANTITY
1	1
2	2
3	2
4	3
5	1
6	2
7	1
8	0
9	1
10	2
11	1
12	2
13	0
14	3
15	2
16	1
17	2
18	2
19	0
20	2

DELAY NUMBER	QUANTITY
21	2
22	0
23	2
24	2
25	0
26	2
27	2
28	0
29	1
30	2
31	0
32	0
33	1

INSTRUCTIONS FOR LOADING

HOLE NUMBER	CHARGE LOCATION DISTANCE TO BOTTOM OF CHARGE (ft)	CHARGE WEIGHT (lbs)	DELAY NUMBER	EXPLOSIVE TYPE
1	190.	264.	2	NBL
	146.	264.	3	NBL
	94.	264.	4	NBL
	49.	264.	5	NBL
2	190.	0.	1	NBL
	190.	0.	2	NBL
	190.	264.	3	NBL
	146.	264.	4	NBL
3	190.	0.	12	NBL
	190.	0.	14	NBL
	190.	264.	15	NBL
	138.	264.	18	NBL
4	190.	0.	4	N
	190.	0.	6	N
	190.	495.	7	N
	142.	495.	10	N
5	188.	495.	6	N
	140.	495.	9	N
	92.	495.	11	N
	44.	495.	14	N
6	188.	264.	10	NBL
	144.	264.	12	NBL
	92.	264.	14	NBL
	47.	264.	16	NBL
7	190.	0.	15	NBL
	190.	0.	17	NBL
	190.	330.	18	NBL
	135.	330.	21	NBL
8	189.	330.	17	NBL
	126.	165.	20	NBL
	98.	165.	21	NBL
	63.	330.	24	NBL

HOLE NUMBER	CHARGE LOCATION DISTANCE TO BOTTOM OF CHARGE (ft)	CHARGE WEIGHT (lbs)	DELAY NUMBER	EXPLOSIVE TYPE
9	189.	330.	20	NBL
	126.	165.	23	NBL
	98.	165.	24	NBL
	63.	330.	27	NBL
10	190.	330.	23	NBL
	127.	165.	26	NBL
	99.	165.	27	NBL
	64.	0.	30	NBL
11	190.	330.	26	NBL
	127.	165.	29	NBL
	99.	165.	30	NBL
	64.	330.	33	NBL

PREDICTED FRAGMENTATION

80.00 PERCENT PASSING SIZE = 23.0 INCHES

70.00 PERCENT PASSING SIZE = 18.1 INCHES

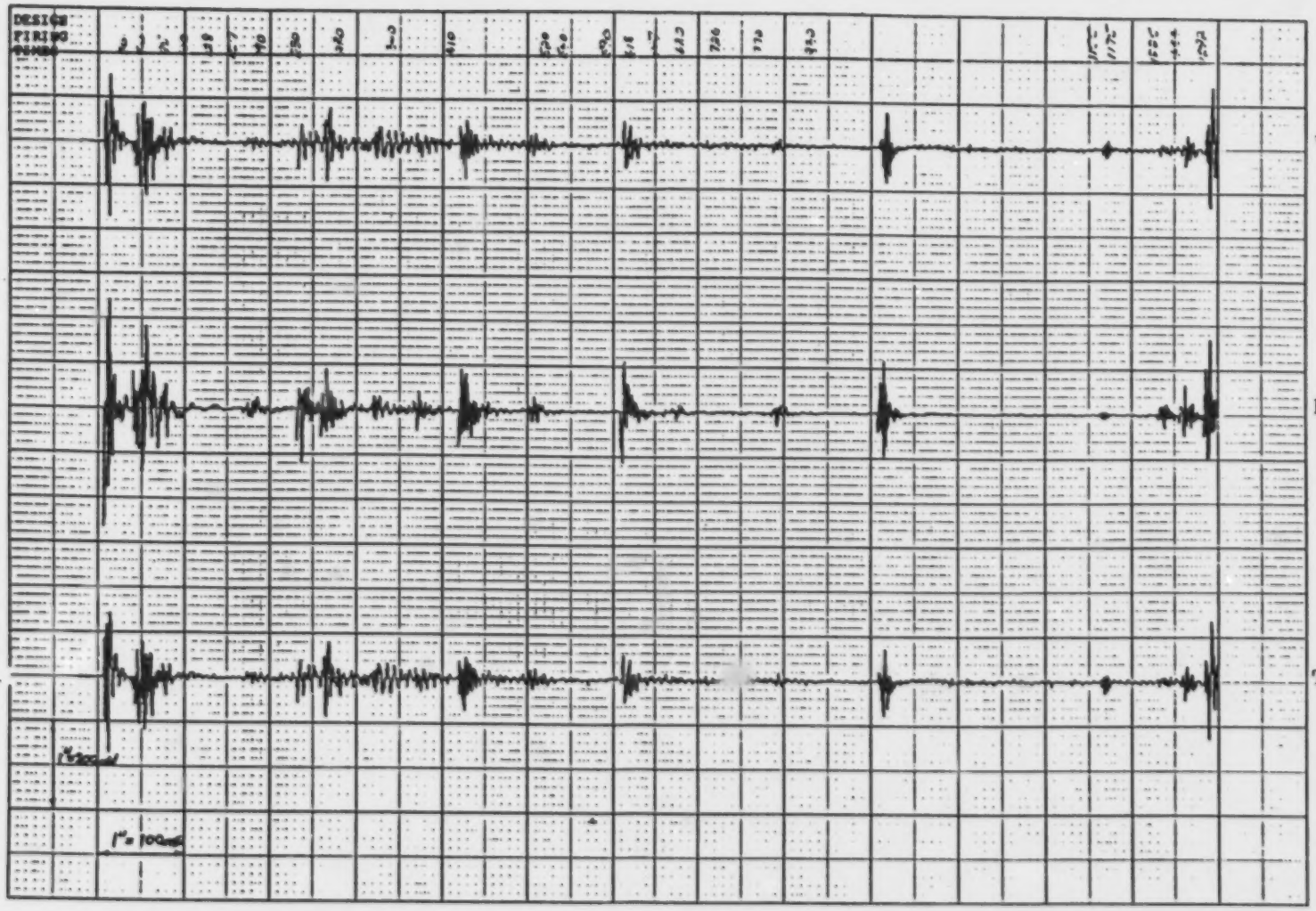
60.00 PERCENT PASSING SIZE = 14.4 INCHES

50.00 PERCENT PASSING SIZE = 11.4 INCHES

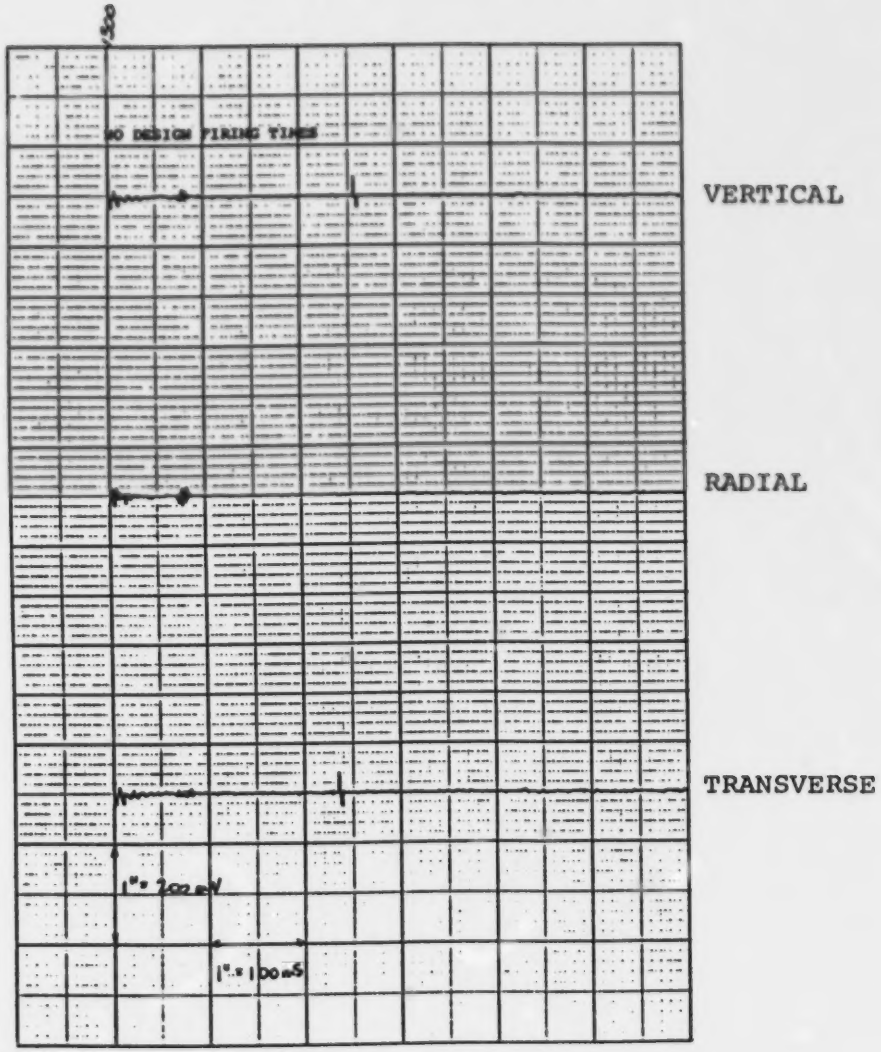
40.00 PERCENT PASSING SIZE = 8.8 INCHES

30.00 PERCENT PASSING SIZE = 6.5 INCHES

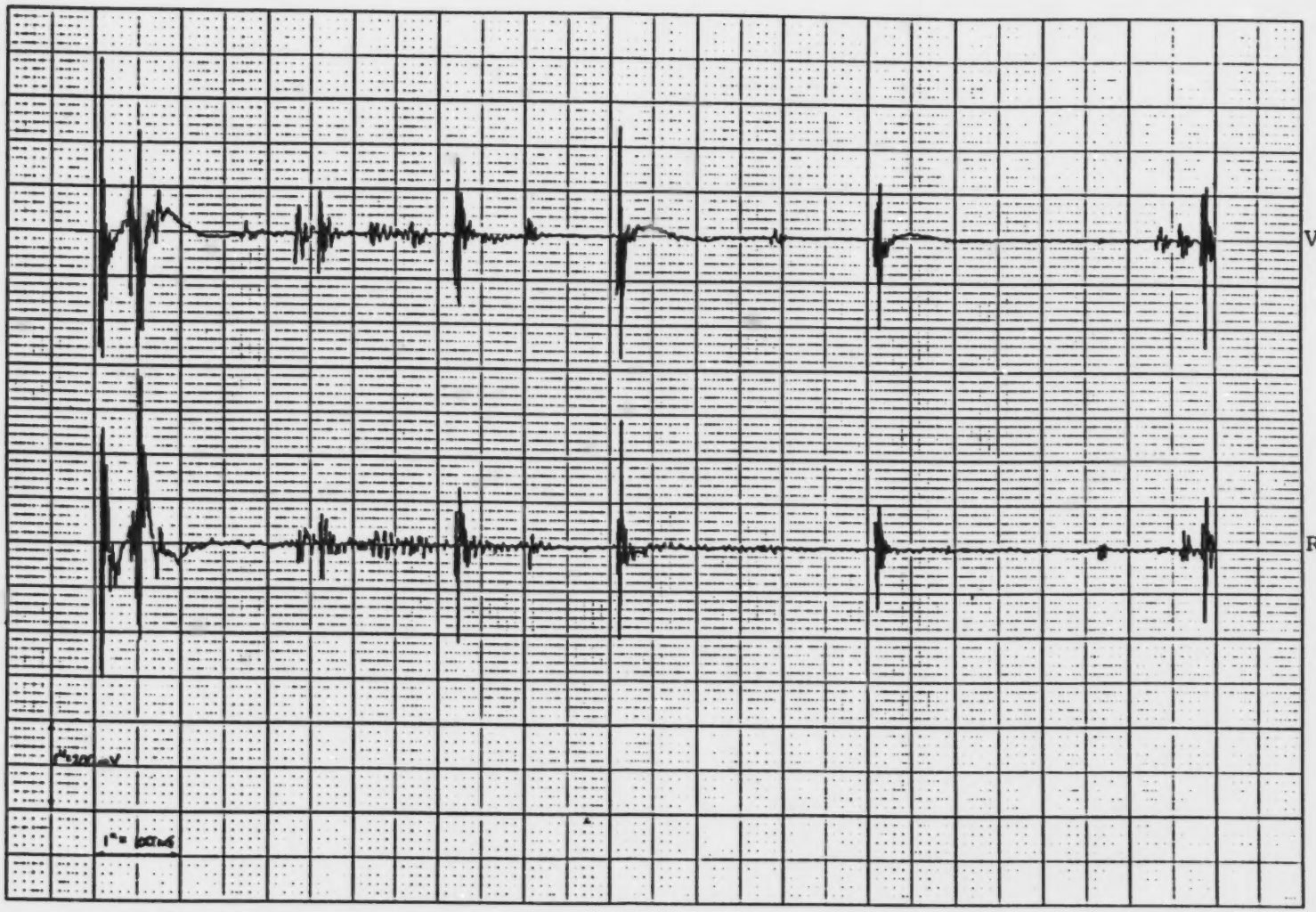
20.00 PERCENT PASSING SIZE = 4.4 INCHES



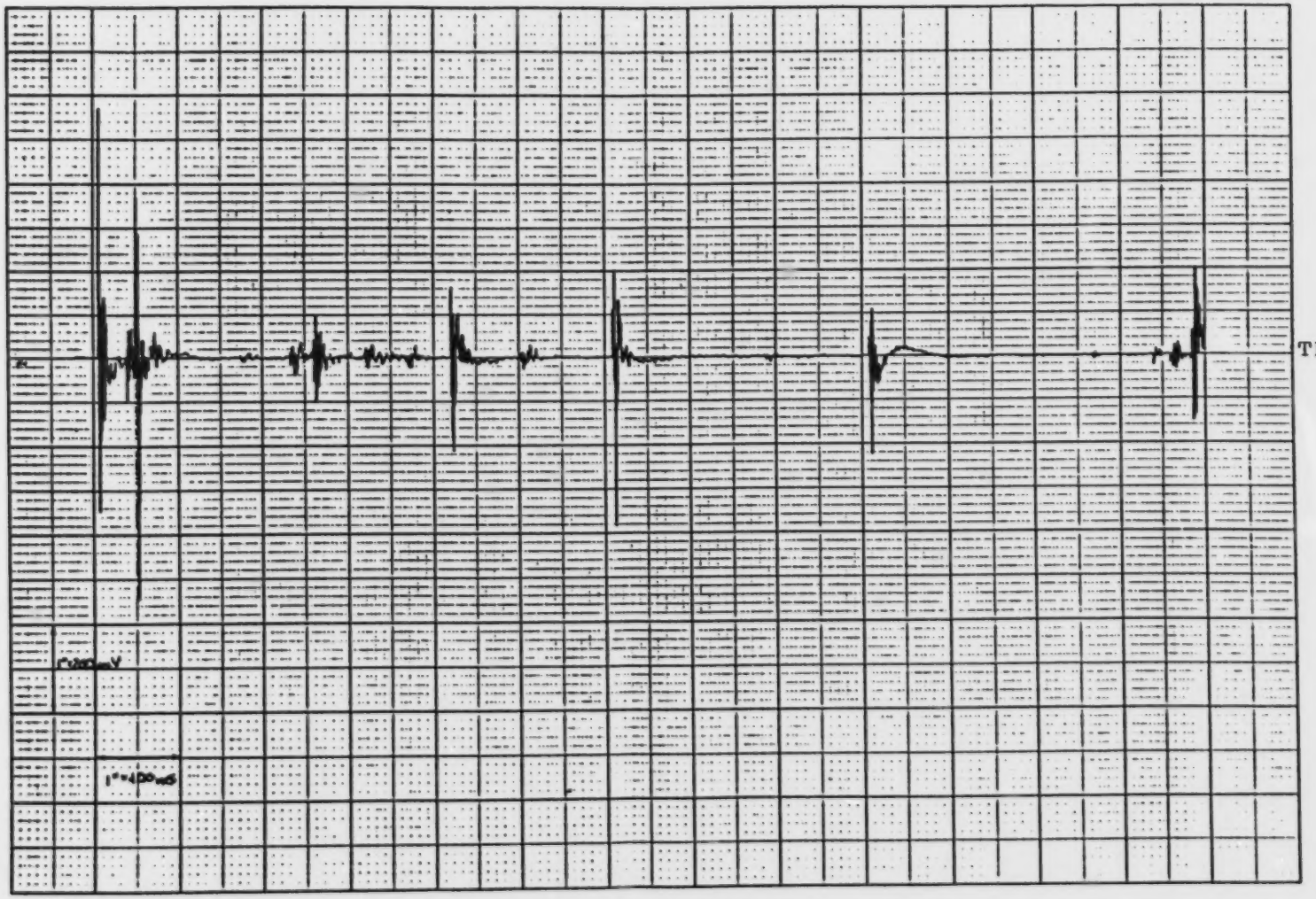
VIBRATION TRACE, 31-151 STOPE (Stn. 1, 0 to 1300 ms)



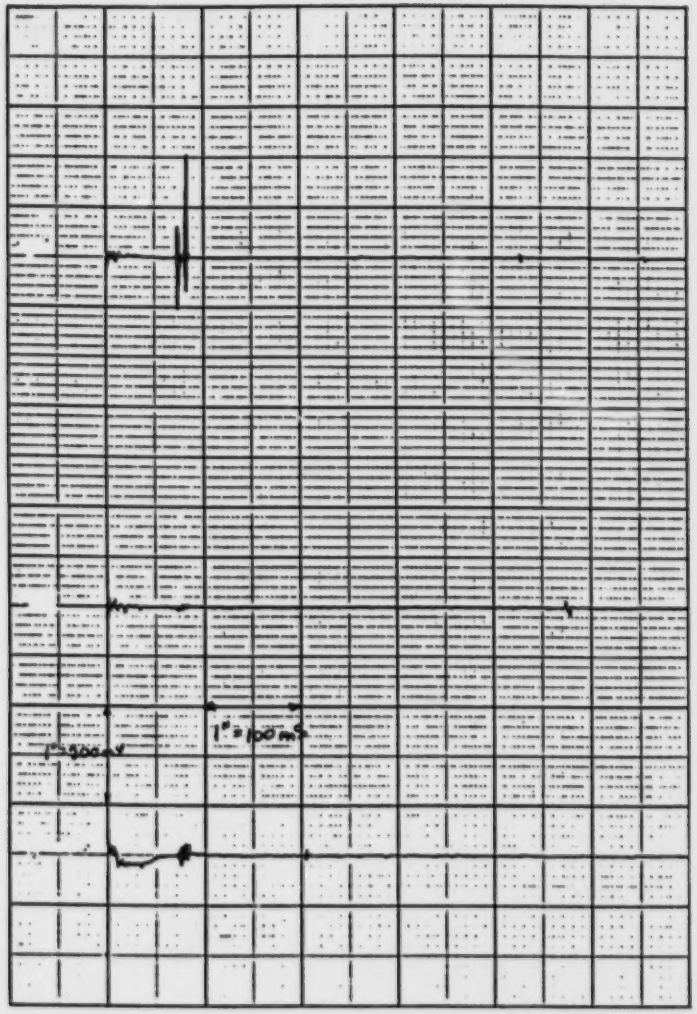
VIBRATION TRACE, 31-151 STOPE (Stn. 1, 1300 to 1900 ms)



VIBRATION TRACE, 31-151 STOPE (Stn. 2, 0 to 1300 ms)



VIBRATION TRACE, 31-151 STOPE (Stn. 2, 0 to 1300 ms)



VIBRATION TRACE, 31-151 STOPE (Stn. 2, 1300 to 1900 ms)

31-151 STOPE UNDERCUT - TAPE 5 FT. EXTENDED

50% PASSING SIZE IS ESTIMATED TO BE 13.4 inches.

DATA AND RESULTS FOR LDBB STOPE 33-176, LOCKERBY MINE

33-176 STOPE HOLE COORDINATES

HOLE #	ROW	COL.	y(ft)	x(ft)	z(ft)
1(16x)	1	1	21.	1747.	9697
			53.5	1750.	9895.5
2(17)	1	4	20.	1762.	9697
			42.	1763.	9895.5
3(18	1	6	20.5	1768.	9697
			37.	1771.5	9895.5
4(19x)	2	1	30.5	1743.5	9697
			57.	1742.5	9895.5
5(16y)	2	2	27.5	1748.	9697
			43.	1748.	9895.5
6(20)	2	3	28.5	1754.	9697
			63.	1753.5	9895.5
7(23x)	2	4	26.	1762.5	9697
			60.	1762.5	9895.5
7(23x)	2	4	26.	1762.5	9697
			60.	1762.5	9895.5
8(18y)	2	5	27.	1766.5	9697
			46.	1776.5	9895.5
9(21)	2	6	29.5	1770.	9697
			53.	1768.5	9895.5
10(23)	3	4	32.	1761.	9697
			64.	1761.	9895.5
11(24)	3	6	34.	1770.	9697
			69.	1766.5	9895.5
12(F1)	4	1	32.5	1746.	9697
			70.5	1746.	9895.5

HOLE #	ROW	COL.	y(ft)	x(ft)	z(ft)
13(F2)	4	2	33.5	1754.	9697
			72.	1754.	9895.5
14(F3)	4	3	35.5	1763.5	9697
			73.5	1763.5	9895.5
15(F4)	4	4	38.0	1770.	9697
			76.	1770.	9895.5

REFERENCE DATA

1740.	0.	9895.5	REFERENCE POINT x y z (ft)
45.	50.	202.	STOPE LENGTH, WIDTH, DEPTH (ft)
0.			REFERENCE ANGLE (degrees)

33-176 SLOT OUTLINE

HOLE #	x(ft)	y(ft)	z(ft)
1	1740	13.	9697
	1740	28.5	9895.5
2	1750	16.	9697
	1750	33.5	9895.5
3	1760	16.	9697
	1760	34.5	9895.5
4	1775	13.5	9697
	1775	30.	9895.5
5	1775	0	9697
	1775	0	9895.5
6	1740	0	9697
	1740	0	9895.5

- see users manual for description of slot outline data development

POWDER FACTOR = $\frac{9768}{14000}$ = 0.7 lb/ton

Burden, spacing = 10 ft, 10 ft

Nilite FR = N ρ = 0.031 Weight Strength = 1
NBL 339 = NBL ρ = 0.015 Weight Strength = .92

33-176 INTERACTIVE INPUT

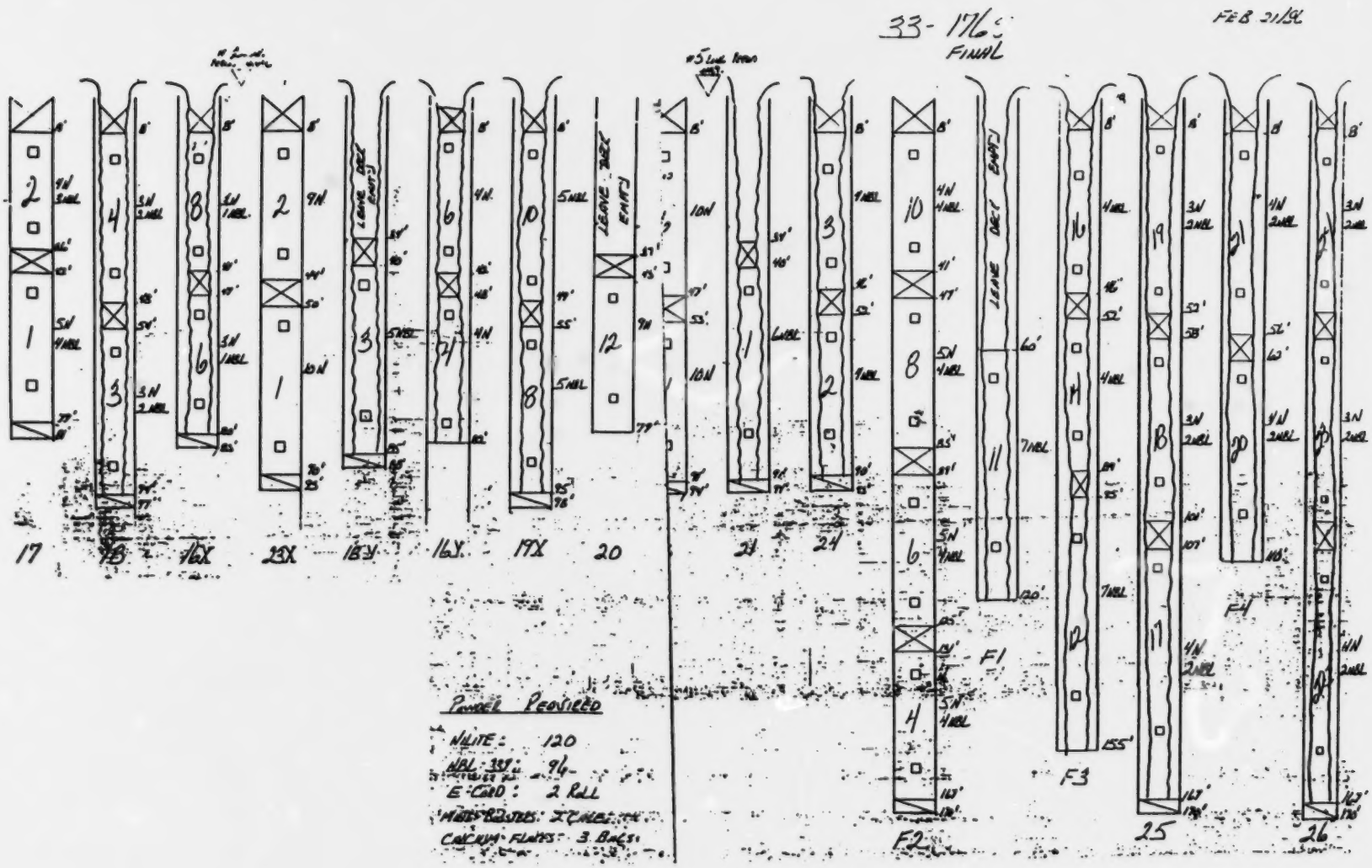
HOLE #	DISTANCE FROM BOTTOM SEPARATION DISTANCE BETWEEN DECKS	WEIGHT (lbs)	EXPLOSIVE	DELAY SEQUENCE	SEPARATION DISTANCE BETWEEN DECKS	WEIGHT (lbs)	EXPLOSIVE	DELAY SEQUENCE
1	18	198	E	6	6	198	E	8
2	19	407	B	1	6	319	B	2
3	4	231	F	3	6	231	F	4
4	3	165	D	18	6	165	D	20
5	16	220	G	14	6	220	G	16
6	19	495	N	12	6	0	N	12
7	8	495	N	11	6	550	N	22
8	13	165	D	13	6	0	D	13
9	7	198	D	31	6	0	D	31
10	7	550	N	24	6	550	N	26
11	8	132	D	32	6	132	D	33

Explosive Combinations

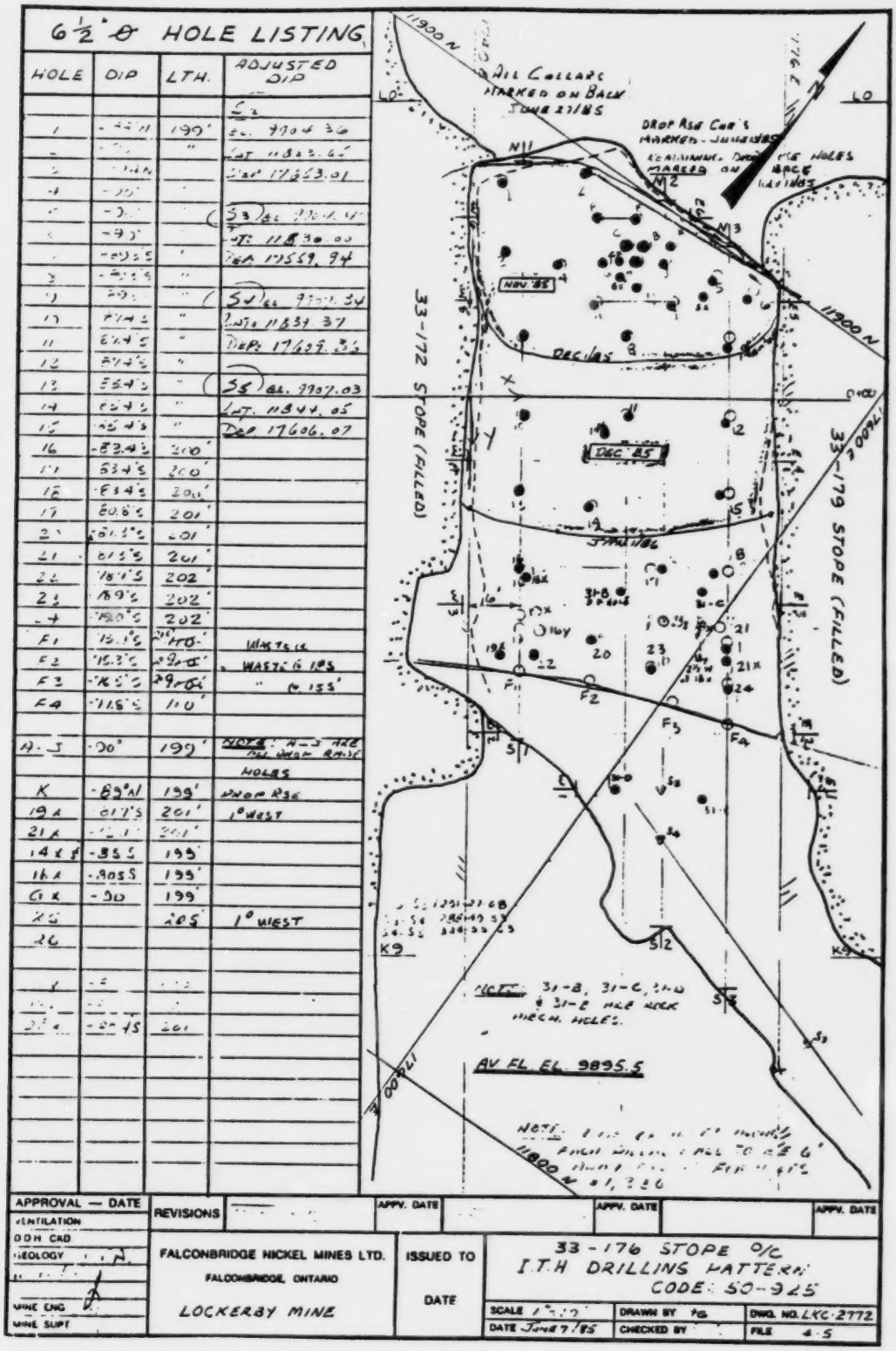
A = 66 lbs NBL and 220 lbs Nilite
= 0.027 Weight Strength = .98

B = 165 lbs NBL and 330 lbs Nilite
= 0.026 Weight Strength = .97

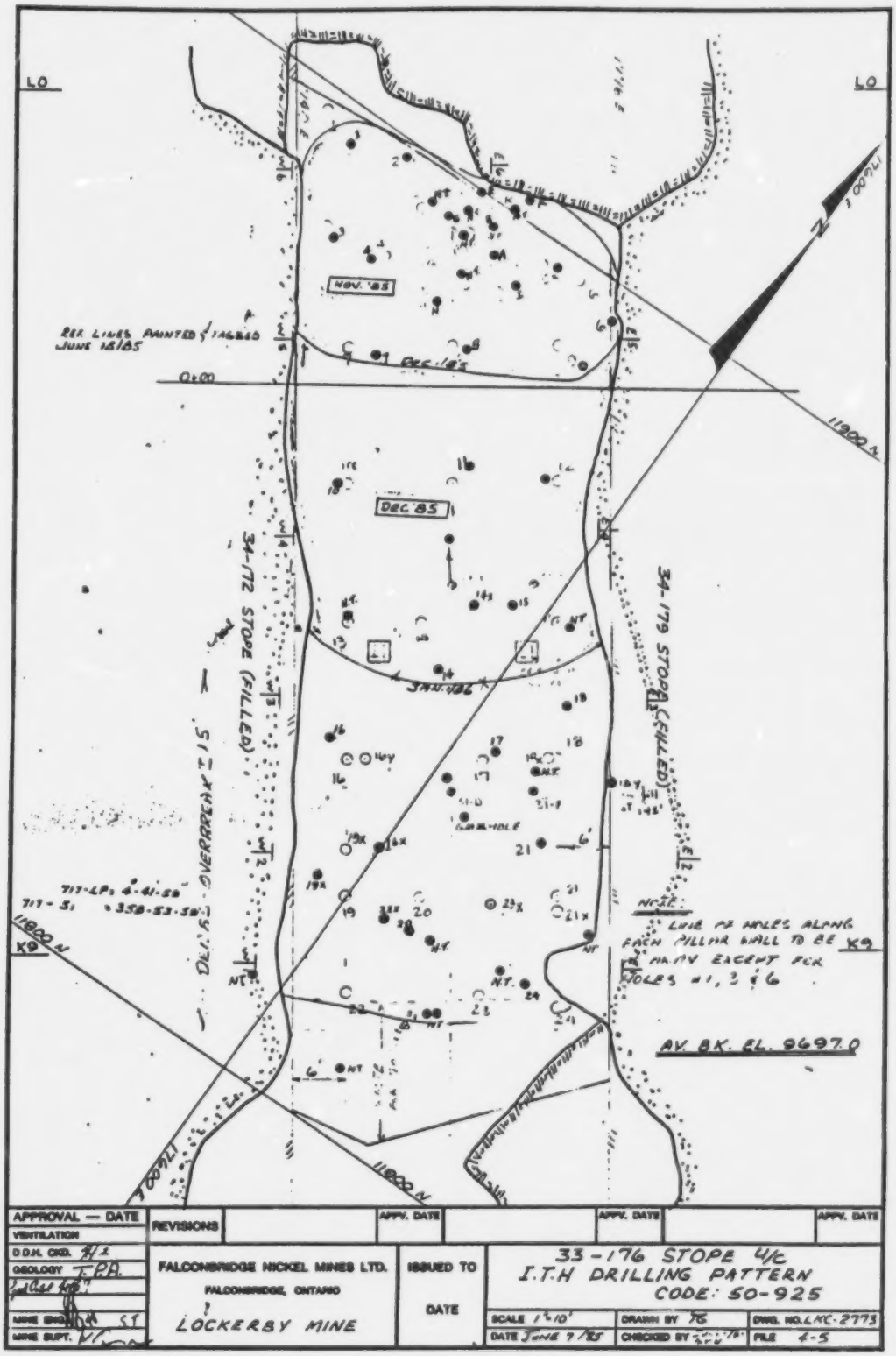
D = Decoupled NBL
E = Decoupled A
F = Decoupled B
G = Decoupled Nilite



LOADING INSTRUCTIONS, 33-176 STOPE



DRILLING PLAN, 33-176 STOPE OVERCUT



DRILLING PLAN, 33-176 STOPE UNDERCUT

FALCONBRIDGE 33-176 STOPE

PROGRAM LDBB RESULTS

WRITTEN FOR THE DESIGN OF THE BLAST IN AN UNDERGROUND STOPE USING THE LARGE DIAMETER BLASTHOLE BENCHING METHOD.

EXPLOSIVE USED: N
DENSITY: 0.0310 LBS/CUBIC INCH
DIAMETER: 6.5000 INCH

INITIATION SEQUENCE IN LEVEL #1

HOLE NUMBER	DELAY PERIOD
1	6
2	1
3	3
4	18
5	14
6	12
7	11
8	13
9	31
10	24
11	32

WEIGHT OF EXPLOSIVE DECKS IN LEVEL #1

HOLE NUMBER	WEIGHT (LBS)	EXPLOSIVE TYPE*
1	198.	E
2	407.	B
3	231.	F
4	165.	D
5	220.	G
6	495.	N
7	495.	N
8	165.	D
9	198.	D
10	550.	N
11	132.	E

* see input data for explosive type definitions.

PLAN VIEW AT [illegible] 80.0000

INITIATION SEQUENCE IN LEVEL #2

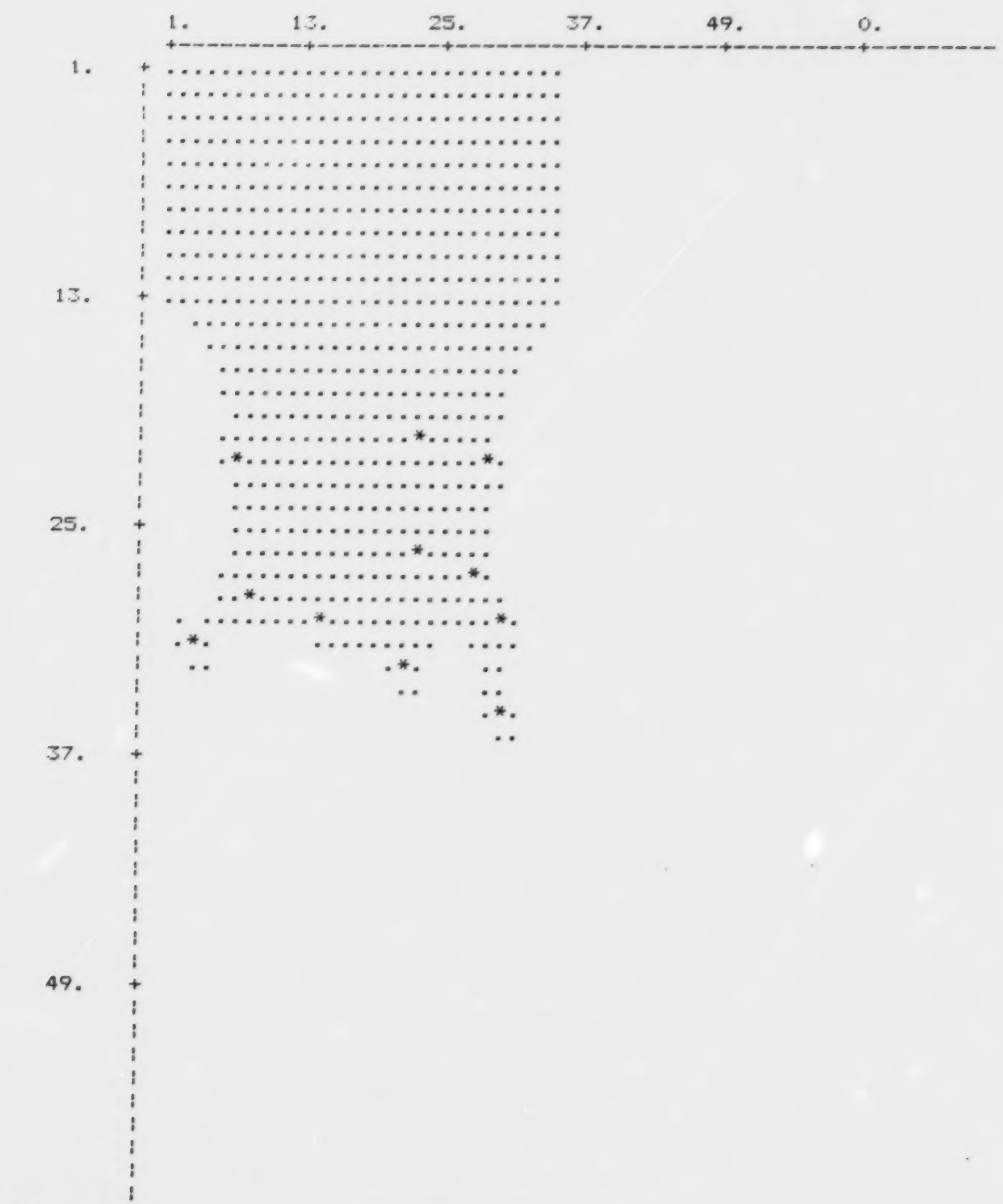
HOLE NUMBER	DELAY PERIOD
1	8
2	2
3	4
4	20
5	16
6	13
7	23
8	14
9	32
10	27
11	34

WEIGHT OF EXPLOSIVE DECKS IN LEVEL #2

HOLE NUMBER	WEIGHT (LBS)	EXPLOSIVE TYPE*
1	198.	E
2	319.	B
3	231.	F
4	165.	D
5	220.	G
6	0.	N
7	550.	N
8	0.	D
9	0.	D
10	550.	N
11	132.	D

* see input for explosive type definitions.

PLAN VIEW AT DEPTH 28.7962



SUMMARY

TOTAL WEIGHT OF EXPLOSIVE: 10428. LBS

DELAY NUMBER	QUANTITY
1	1
2	1
3	1
4	1
5	0
6	1
7	0
8	1
9	0
10	0
11	1
12	1
13	2
14	2
15	0
16	1
17	0
18	1
19	0
20	1

DELAY NUMBER	QUANTITY
21	0
22	0
23	1
24	1
25	0
26	0
27	1
28	0
29	0
30	0
31	1
32	2
33	0
34	1

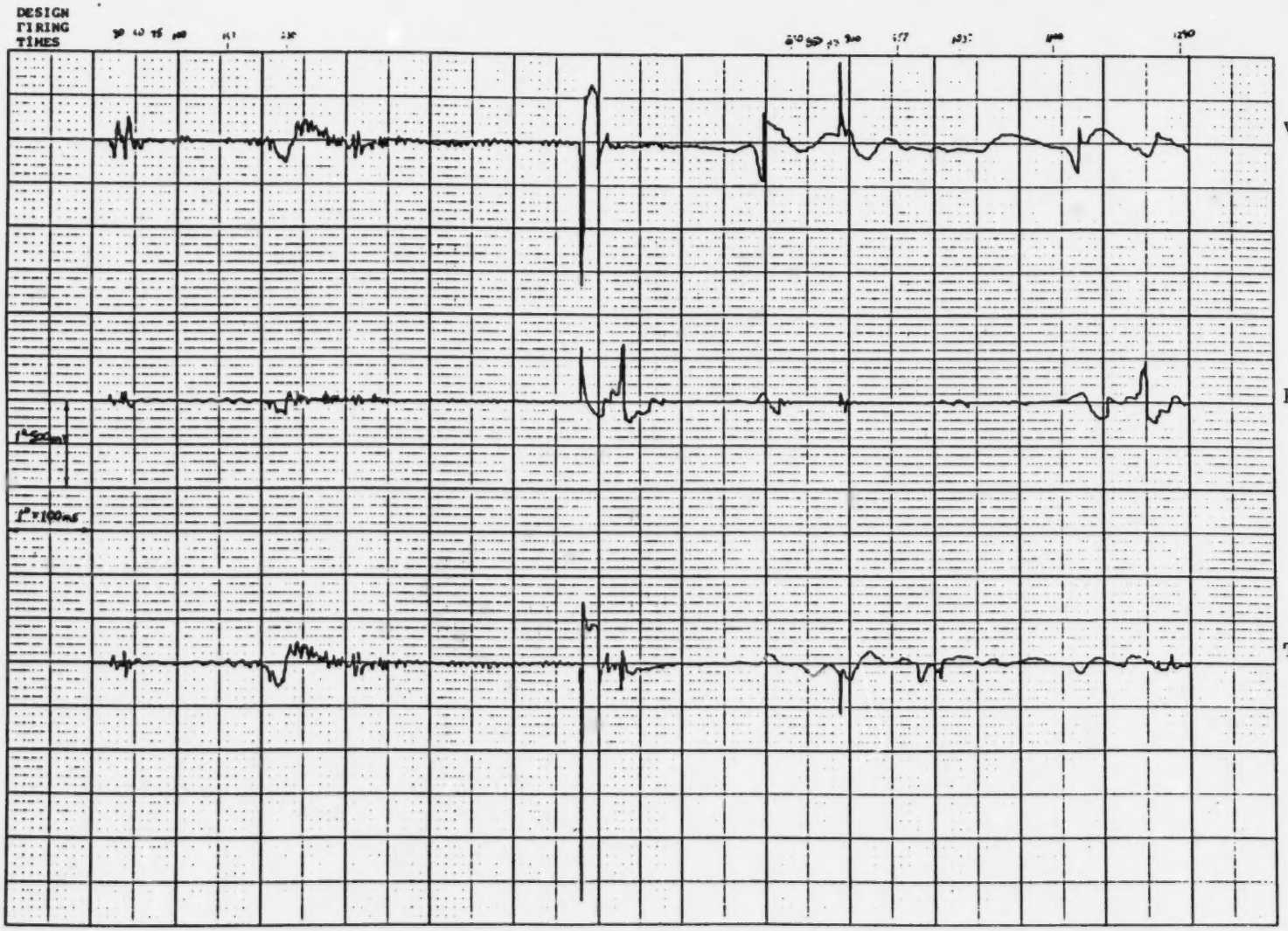
INSTRUCTIONS FOR LOADING

HOLE NUMBER	CHARGE LOCATION DISTANCE TO BOTTOM OF CHARGE (ft)	CHARGE WEIGHT (lbs)	DELAY NUMBER	EXPLOSIVE* TYPE
1	81.	198.	6	E
	29.	198.	8	E
2	79.	407.	1	B
	34.	286.	2	B
3	94.	231.	3	F
	30.	231.	4	F
4	96.	165.	18	D
	49.	165.	20	D
5	82.	220.	14	G
	30.	220.	16	G
6	80.	495.	12	N
	33.	0.	13	N
7	91.	495.	11	N
	44.	550.	23	N
8	85.	165.	13	D
	10.	0.	14	D
9	91.	198.	31	D
	2.	0.	32	D
10	92.	550.	24	N
	41.	550.	27	N
11	91.	132.	32	E
	54.	132.	34	D

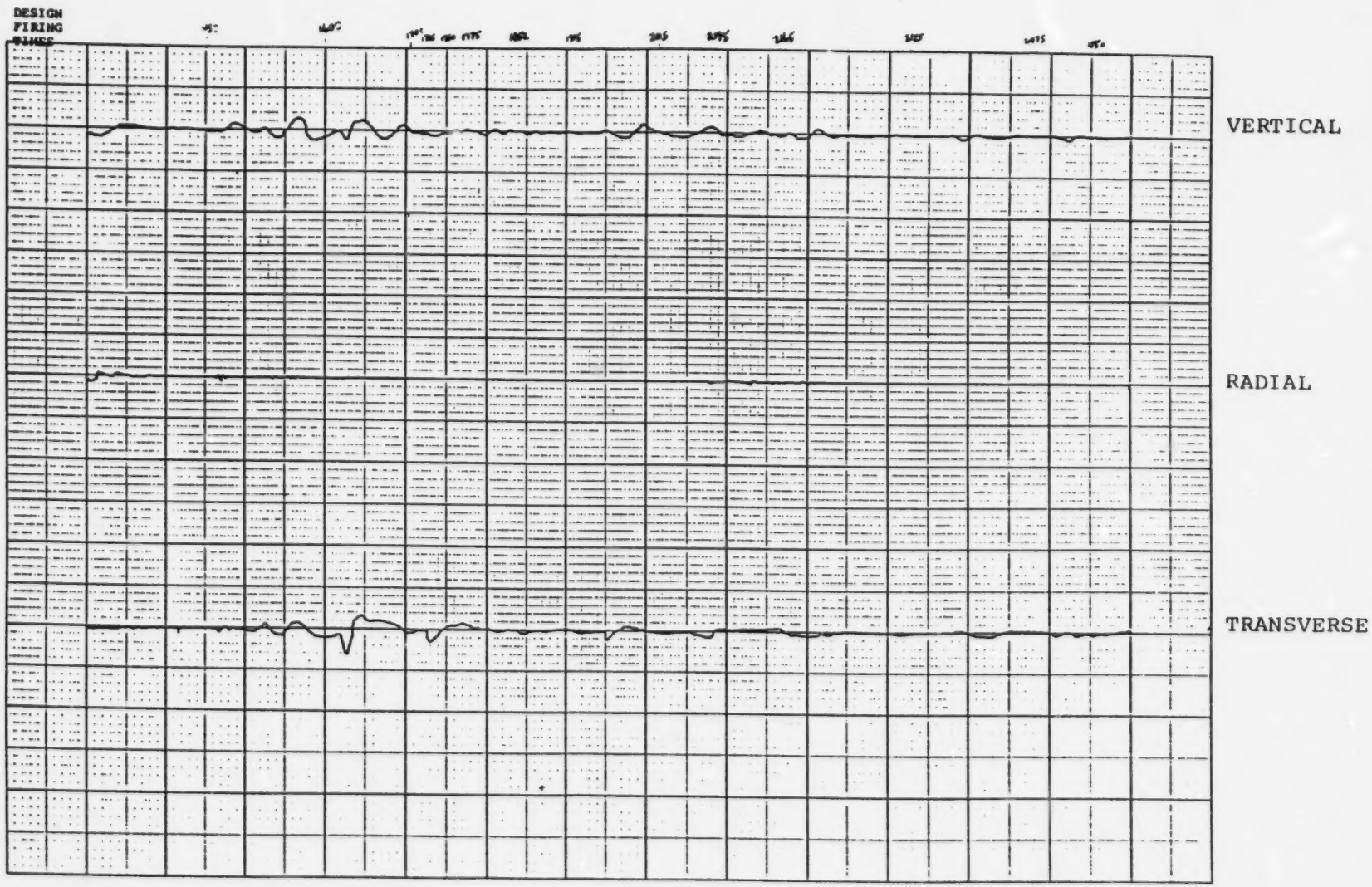
* N = Nilite FR (ANFO)
NBL = NBL 339 (low density ANFO)
A = 10:3 Nilite:NBL
B = 2:1 Nilite:NBL
D = decoupled NBL
E = decoupled A
F = decoupled B
G = decoupled Nilite

PREDICTED FRAGMENTATION

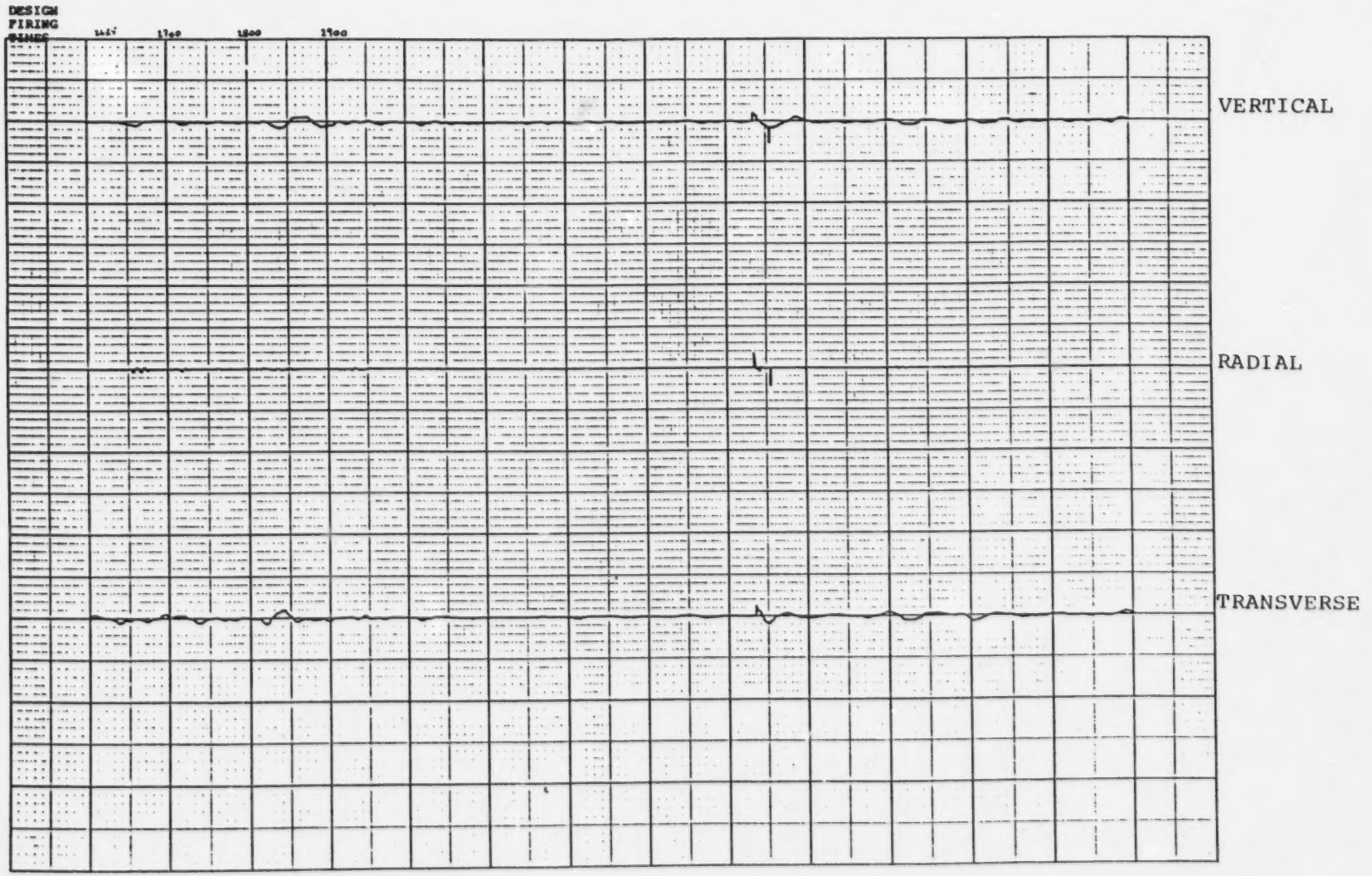
80.00	PERCENT PASSING SIZE =	59.1	INCHES
70.00	PERCENT PASSING SIZE =	37.3	INCHES
60.00	PERCENT PASSING SIZE =	24.2	INCHES
50.00	PERCENT PASSING SIZE =	15.6	INCHES
40.00	PERCENT PASSING SIZE =	9.6	INCHES
30.00	PERCENT PASSING SIZE =	5.4	INCHES
20.00	PERCENT PASSING SIZE =	2.6	INCHES



VIBRATION TRACE, 33-176 STOPE (Stn. 1, 0 to 1300 ms)



VIBRATION TRACE, 33-176 STOPE (Stn. 1, 1300 to 2600 ms)



VIBRATION TRACE, 33-176 STOPE (Stn. 1, 2600 to 3900 ms)

DATA AND RESULTS FOR LDBB STOPE 27-165, LOCKERBY MINE

27-165 HOLE COORDINATES

HOLE #	ROW	COLUMN	x(ft)	y(ft)	z(ft)
1(7)	1	1	8. 15.	1682 1682	10225 10395
2(7 x b)	1	2	10.5 30.	1688 1688	10225 10395
3(8)	1	3	17. 39.5	1687 1679	10225 10395
4(7 x a)	2	1	8. 11.5	1690 1688	10225 10395
5(6)	2	2	13. 34.	1689.5 1689.	10225 10395
6(8 x)	2	3	17.5 45.5	1691.5 1685.	10225 10395
7(4)	3	1	7.5 18.	1695. 1700.	10225 10395
8(5)	3	3	15. 37.5	1695. 1692.	10225 10395
9(1)	4	1	6.5 18.	1703. 1705.5	10225 10395
10(2)	4	2	11.5 42.5	1703. 1700.5	10225 10395
11(3)	4	3	16.5 28.5	1703. 1699.	10225 10395

27-165 SLOT OUTLINE

HOLE #	x(ft)	y(ft)	z(ft)
1	0	1668	10225
	24.5	1668	10395
2	7	1680.5	10225
	19	1679	10395
3	11	1687	10225
	33	1678	10395
4	19.5	1680.5	10225
	46	1682	10395
5	19	1668	10225
	45	1668	10395

see users manual for description of slot data development

27-165 REFERENCE DATA

0	1668	10225	REFERENCE POINT x y z (ft)
45	40	170	STOPE WIDTH LENGTH DEPTH (ft)
0			REFERENCE ANGLE (degrees)

31-151 INTERACTIVE INPUT

HOLE #	DIST. FROM BOTTOM SEPARATION DISTANCE BETWEEN DECKS (ft)	WEIGHT (lbs)	EXPLOSIVE	DELAY SEQUENCE
LEVEL 1				
1	4	231	NBL	5
2	4	440	N	2
3	29	0	NBL	1
4	4	231	NBL	9
5	4	231	NBL	6
6	3	231	NBL	8
7	5	440	N	13
8	3	231	NBL	11
9	5	231	NBL	20
10	4	231	NBL	16
11	3	231	NBL	18
LEVEL 2				
1	0	231	NBL	5
2	8	440	N	3
3	29	0	NBL	1
4	0	231	NBL	0
5	0	231	NBL	6

HOLE #	DIST. FROM BOTTOM SEPARATION DISTANCE BETWEEN DECKS (ft)	WEIGHT (lbs)	EXPLOSIVE	DELAY SEQUENCE
6	0	231	NBL	8
7	8	440	N	14
8	0	231	NBL	11
9	0	231	NBL	20
10	0	231	NBL	16
11	0	231	NBL	18
LEVEL 3				
1	8	0	NBL	5
2	8	429	NBL	4
3	28	462	NBL	1
4	8	462	NBL	10
5	8	462	NBL	7
6	8	0	NBL	8
7	8	429	NBL	15
8	9	462	NBL	12
9	9	462	NBL	21
10	8	462	NBL	17
11	9	462	NBL	19

N = Nilite FR (ANFO)

NBL = NBL339 (low density ANFO)

MISC. DATA

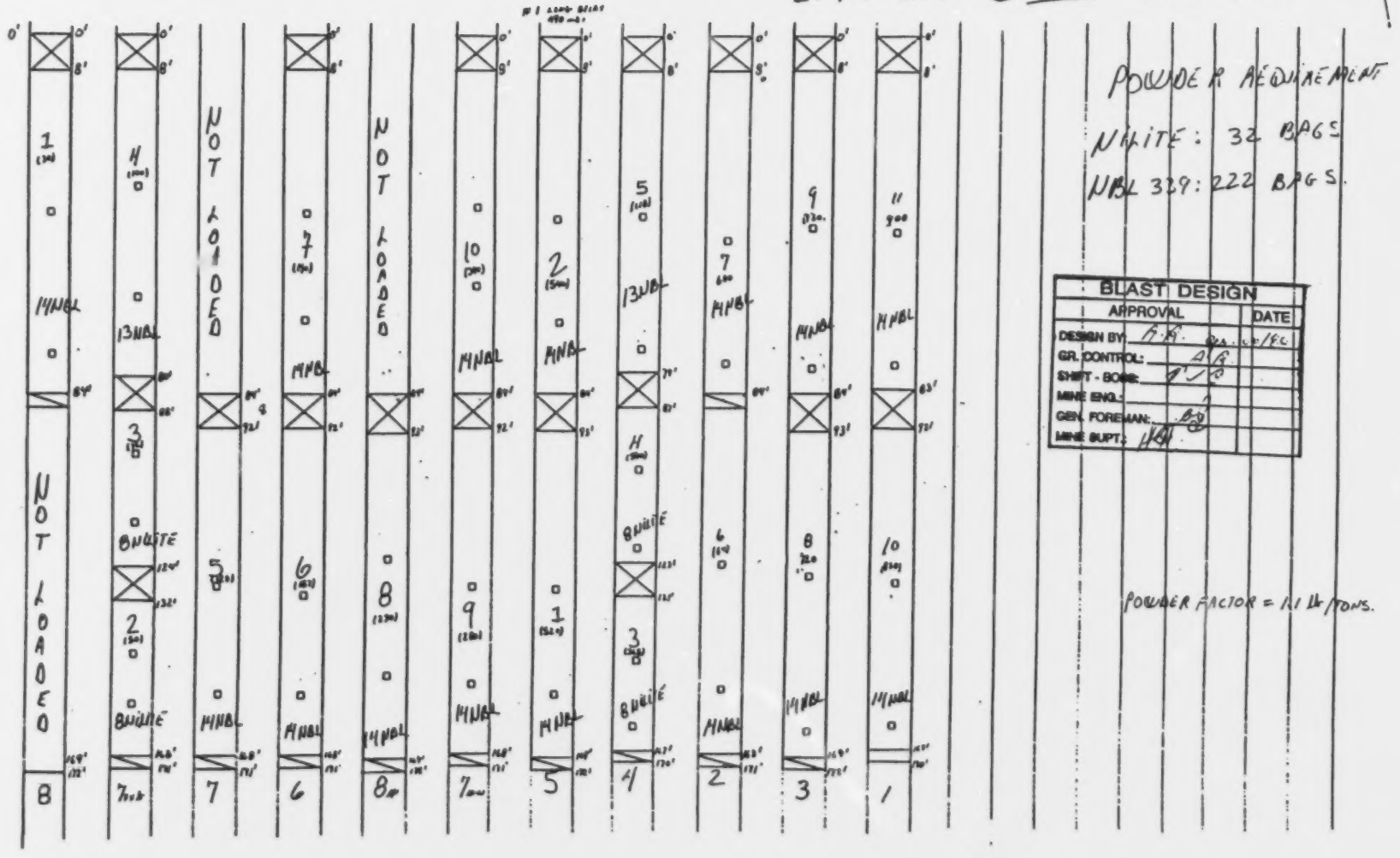
Nilite = N ρ = 0.031 lb/cu.in. WEIGHT STRENGTH = 1

NBL = NBL ρ = 0.015 lb/cu.in. WEIGHT STRENGTH = 0.92

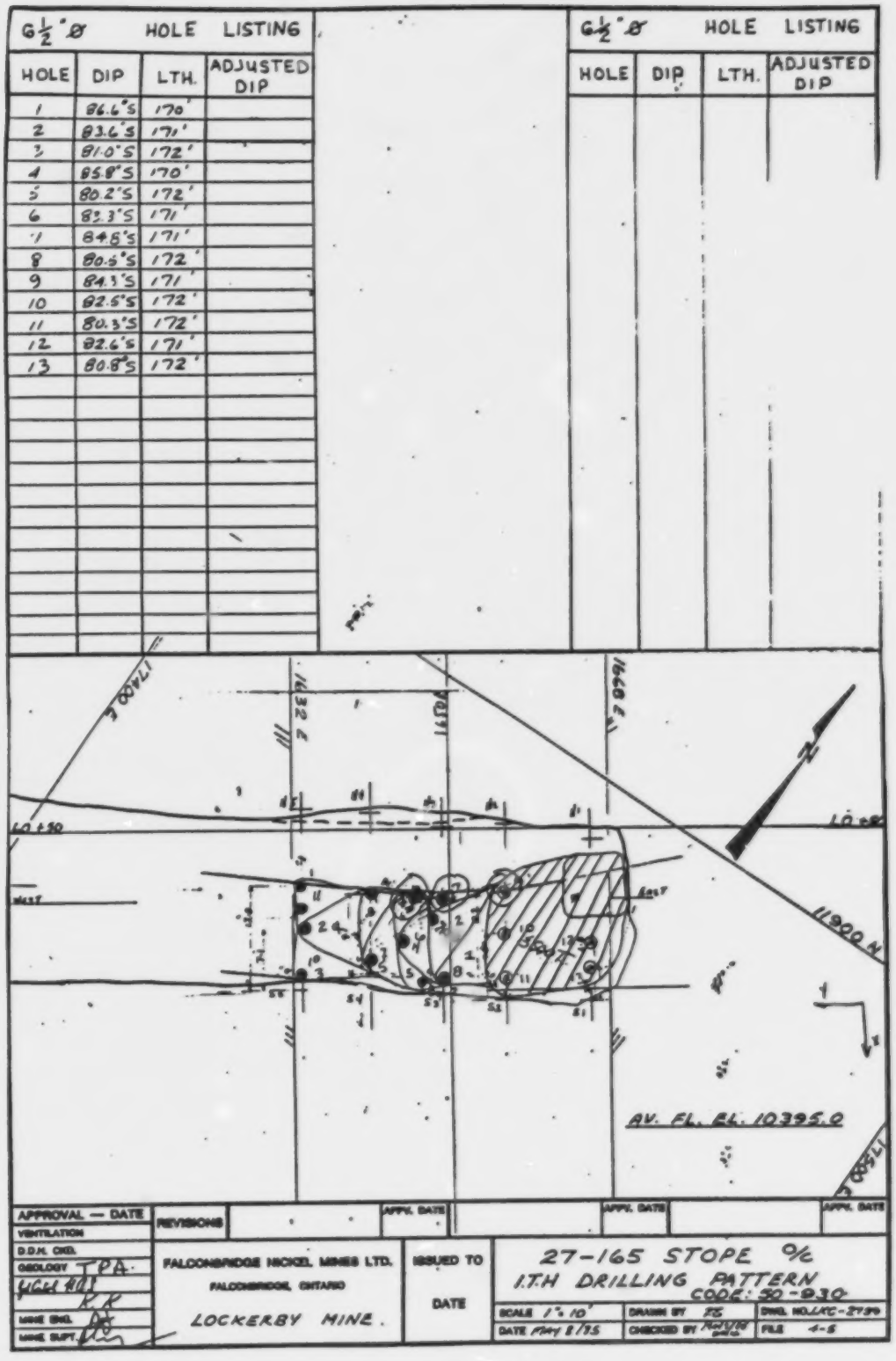
$$\text{POWDER FACTOR} = \frac{9{,}086 \text{ lbs}}{10{,}160 \text{ tons}} = 0.9 \text{ lbs/ton}$$

$$= 0.10 \text{ lbs/cu.in.}$$

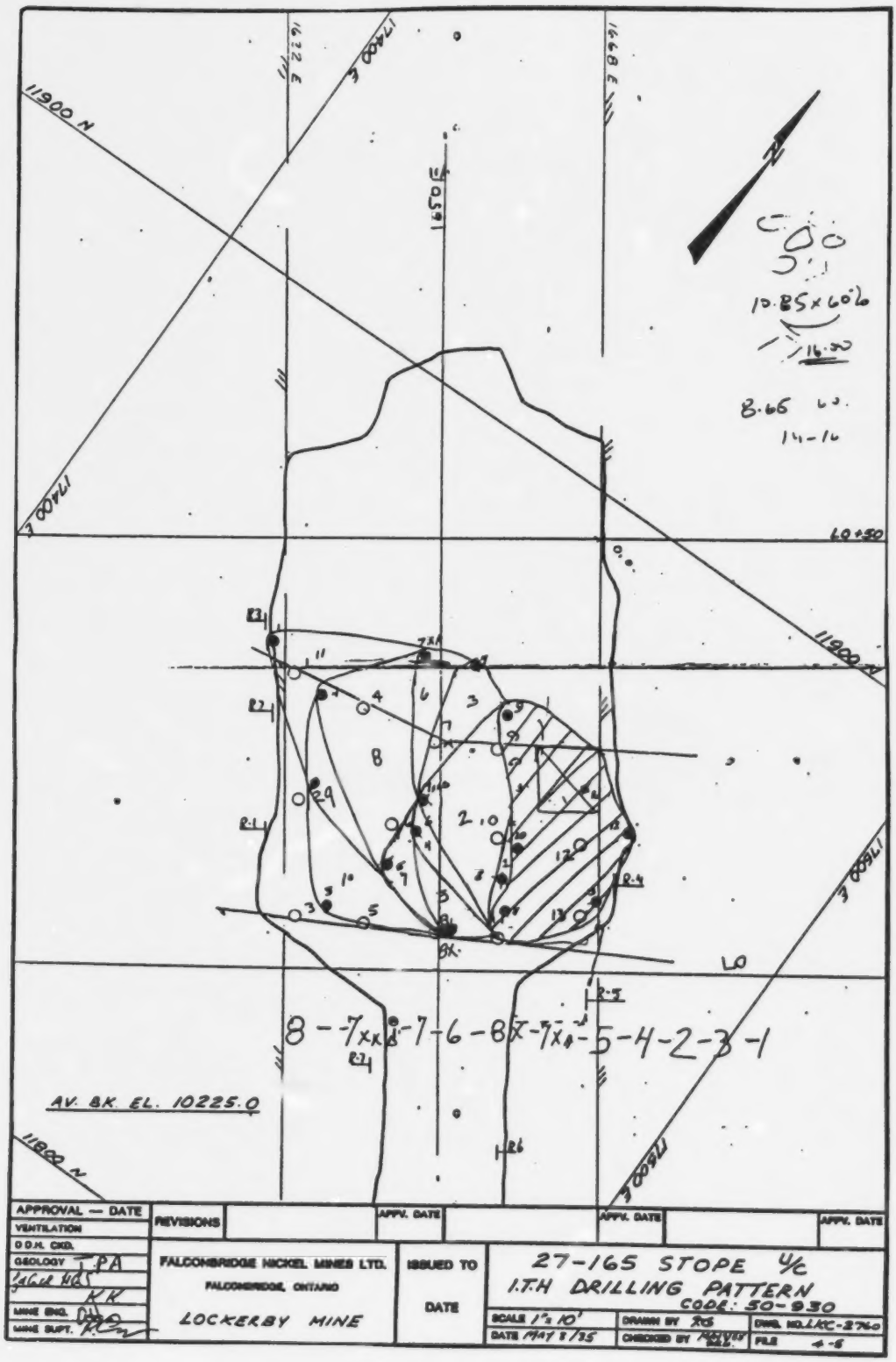
Burden, spacing = 5 ft., 7.5 ft.



LOADING INSTRUCTIONS 27-165 STOPE



DRILLING PLAN, 27-165 STOPE OVERCUT



DRILLING PLAN, 27-165 STOPE UNDERCUT

FALCONBRIDGE 27-165

PROGRAM LDBB RESULTS

WRITTEN FOR THE DESIGN OF THE BLAST IN AN UNDERGROUND STOPE USING THE LARGE DIAMETER BLASTHOLE BENCHING METHOD.

EXPLOSIVE USED: NBL
DENSITY: 0.0150 LBS/CUBIC INCH
DIAMETER: 6.5000 INCH

INITIATION SEQUENCE IN LEVEL #1

HOLE NUMBER	DELAY PERIOD
1	5
2	2
3	1
4	9
5	6
6	8
7	13
8	11
9	20
10	16
11	18

WEIGHT OF EXPLOSIVE DECKS IN LEVEL #1

HOLE NUMBER	WEIGHT (LBS)	EXPLOSIVE TYPE
1	231.	NBL
2	440.	N
3	0.	NBL
4	231.	NBL
5	231.	NBL
6	231.	NBL
7	440.	N
8	231.	NBL
9	231.	NBL
10	231.	NBL
11	231.	NBL

N = Nilite FR (ANFO)

NBL = NBL339 (low density ANFO)

PLAN VIEW AT DEPTH 169.0000

INITIATION SEQUENCE IN LEVEL #2

HOLE NUMBER	DELAY PERIOD
1	6
2	3
3	2
4	11
5	8
6	10
7	16
8	13
9	22
10	18
11	20

WEIGHT OF EXPLOSIVE DECKS IN LEVEL #2

HOLE NUMBER	WEIGHT (LBS)	EXPLOSIVE TYPE
1	231.	NBL
2	440.	N
3	0.	NBL
4	231.	NBL
5	231.	NBL
6	231.	NBL
7	440.	N
8	231.	NBL
9	231.	NBL
10	231.	NBL
11	231.	NBL

N = Nilite FR (ANFO)

NBL = NBL339 (low density ANFO)

PLAN VIEW AT DEPTH 130.3256

INITIATION SEQUENCE IN LEVEL #3

HOLE NUMBER	DELAY PERIOD
1	7
2	4
3	3
4	14
5	11
6	12
7	19
8	16
9	25
10	21
11	23

WEIGHT OF EXPLOSIVE DECKS IN LEVEL #3

HOLE NUMBER	WEIGHT (LBS)	EXPLOSIVE TYPE
1	0.	NBL
2	429.	NBL
3	462.	NBL
4	462.	NBL
5	462.	NBL
6	0.	NBL
7	429.	NBL
8	462.	NBL
9	462.	NBL
10	462.	NBL
11	462.	NBL

N = Nilite FR (ANFO)

NBL = NBL339 (low density ANFO)

PLAN VIEW AT DEPTH 83.6513

SUMMARY

TOTAL WEIGHT OF EXPLOSIVE: 9548. LBS

DELAY NUMBER	QUANTITY
1	1
2	2
3	2
4	1
5	1
6	2
7	1
8	2
9	1
10	1
11	3
12	1
13	2
14	1
15	0
16	3
17	0
18	2
19	1
20	2

DELAY NUMBER	QUANTITY
21	1
22	1
23	1
24	0
25	1

INSTRUCTIONS FOR LOADING

HOLE NUMBER	CHARGE LOCATION DISTANCE TO BOTTOM OF CHARGE (ft)	CHARGE WEIGHT (lbs)	DELAY NUMBER	EXPLOSIVE TYPE
1	169.	231.	5	NBL
	130.	231.	6	NBL
	84.	0.	7	NBL
2	170.	440.	2	N
	126.	440.	3	N
	82.	429.	4	NBL
3	145.	0.	1	NBL
	116.	0.	2	NBL
	87.	462.	3	NBL
4	169.	231.	9	NBL
	130.	231.	11	NBL
	84.	462.	14	NBL
5	170.	231.	6	NBL
	131.	231.	8	NBL
	84.	462.	11	NBL
6	172.	231.	8	NBL
	133.	231.	10	NBL
	86.	0.	12	NBL
7	168.	440.	13	N
	125.	440.	16	N
	81.	429.	19	NBL
8	171.	231.	11	NBL
	132.	231.	13	NBL
	84.	462.	16	NBL

HOLE NUMBER	CHARGE LOCATION DISTANCE TO BOTTOM OF CHARGE (ft)	CHARGE WEIGHT (lbs)	DELAY NUMBER	EXPLOSIVE TYPE
9	168.	231.	20	NBL
	130.	231.	22	NBL
	82.	462.	25	NBL
10	171.	231.	16	NBL
	132.	231.	18	NBL
	84.	462.	21	NBL
11	170.	231.	18	NBL
	132.	231.	20	NBL
	84.	462.	23	NBL

N = Nilite FR (ANFO)
NBL = NBL339 (low density ANFO)

PREDICTED FRAGMENTATION

80.00	PERCENT PASSING SIZE =	20.8	INCHES
70.00	PERCENT PASSING SIZE =	16.1	INCHES
60.00	PERCENT PASSING SIZE =	12.7	INCHES
50.00	PERCENT PASSING SIZE =	9.9	INCHES
40.00	PERCENT PASSING SIZE =	7.6	INCHES
30.00	PERCENT PASSING SIZE =	5.5	INCHES
20.00	PERCENT PASSING SIZE =	3.7	INCHES

27-165 STOPE UNDERCUT

50% PASSING SIZE IS ESTIMATED AS 7.5 inches

APPENDIX B

TEST DATA ON PROGRAM VCRM

DATA AND RESULTS FOR INCO 808.6

HOLE COORDINATES

HOLE #	ROW #	COL. #	x(ft)	y(ft)	z(ft)
1	1	1	26.25	35	10545
			16.25	10	10568
2	1	2	16.25	35	10545
			16.25	10	10588
3	1	3	16.25	37.50	10545
			16.25	10	10620
4	1	4	16.25	38.75	10545
			16.25	10	10665
5	1	5	16.25	40	10545
			16.25	18.75	10686
6	1	6	16.25	43.75	10545
			16.25	30	10675
7	1	7	16.25	46.25	10545
			16.25	40	10692
8	1	8	16.25	50	10545
			16.25	50	10692
9	2	1	31.25	35	10545
			31.25	8.75	10565
10	2	2	31.25	37.50	10545
			31.25	8.75	10595
11	2	3	31.25	37.50	10545
			31.25	8.75	10658
12	2	4	31.25	41.25	10545
			31.25	18.75	10688
13	2	5	31.25	45	10545
			31.25	33.75	10675
14	2	6	31.25	48.75	10545
			31.25	48.75	10693
15	3	1	46.25	33.75	10545
			46.25	8.75	10563

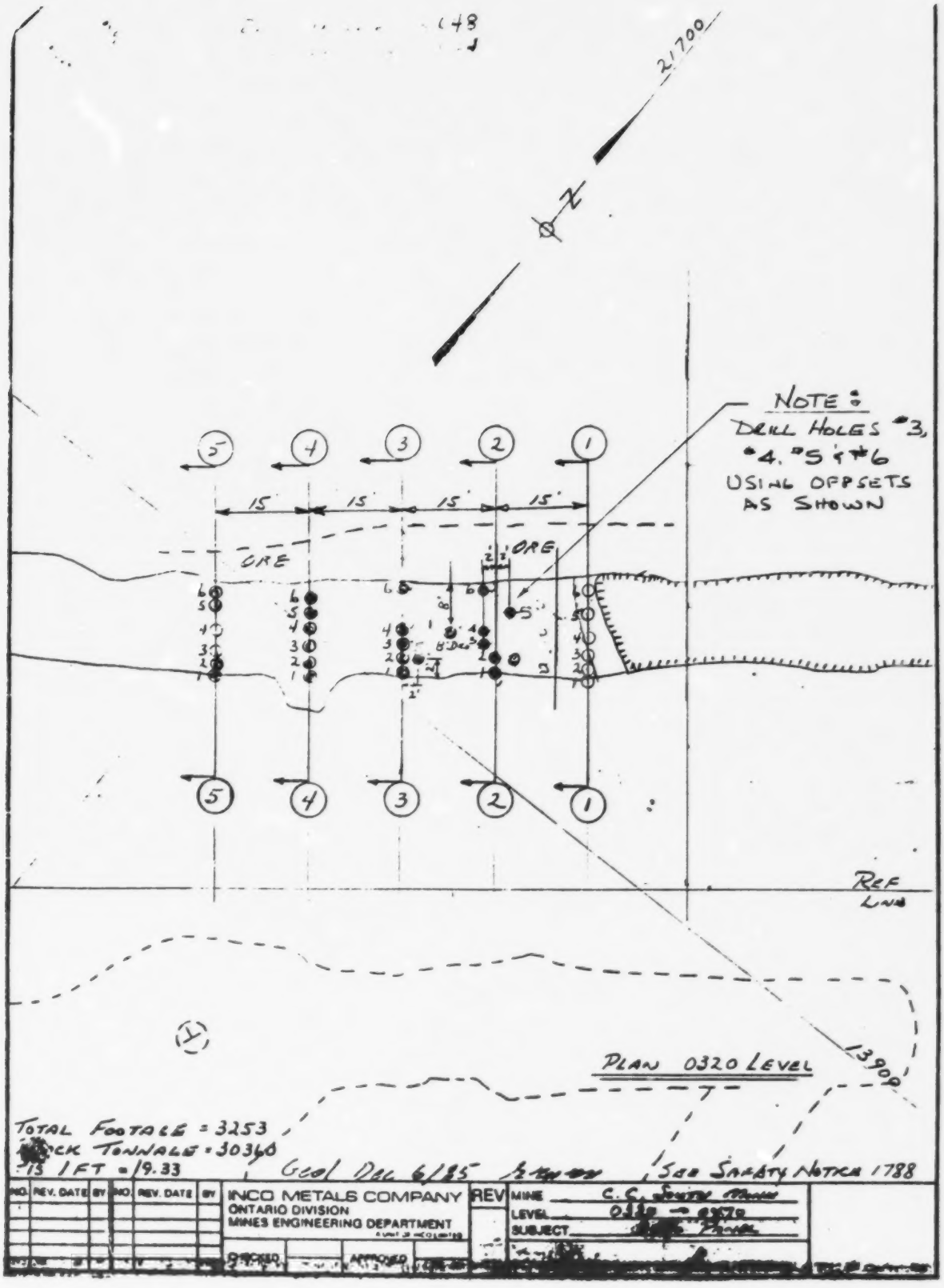
HOLE #	ROW #	COL. #	x(ft)	y(ft)	z(ft)
16	3	2	46.25	36.25	10545
			46.25	8.75	10593
17	3	3	46.25	37.50	10545
			46.25	8.75	10650
18	3	4	46.25	41.25	10545
			46.25	17.25	10690
19	3	5	46.25	36.25	10545
			46.25	35	10678
20	3	6	46.25	47.50	10545
			46.25	50	10660
21	4	1	61.25	35	10545
			61.25	8.75	10575
22	4	2	61.25	37.50	10545
			61.25	8.75	10610
23	4	3	61.25	41.25	10545
			61.25	8.75	10665
24	4	4	61.25	45	10545
			61.25	20	10688
25	4	5	61.25	48.75	10545
			61.25	56.25	10623
26	4	6	61.25	48.75	10545
			61.25	56.25	10623
27	5	1	76.25	35	10545
			76.25	8.75	10563
28	5	2	76.25	35	10545
			76.25	8.75	10595
29	5	3	76.25	37.50	10545
			76.25	8.75	10653
30	5	4	76.25	41.25	10545
			76.25	17.50	10690
31	5	5	76.25	45	10545
			76.25	37.50	10678

HOLE #	ROW #	COL. #	x(ft)	y(ft)	z(ft)
32	5	6	76.25	47.50	10545
			76.25	47.50	10690
33	6	1	39	41	10545
			39	41	10690

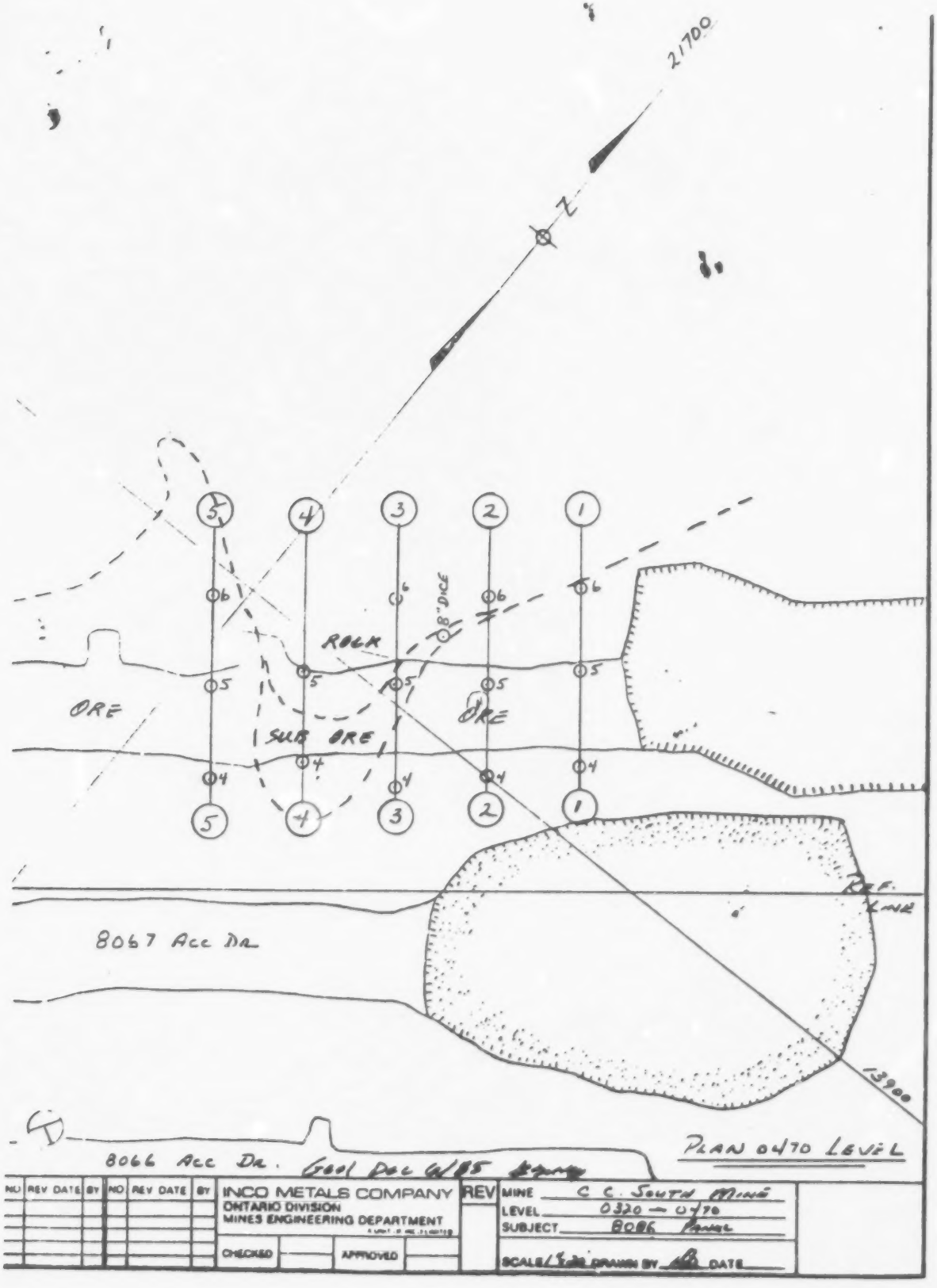
REFERENCE DATA:

INCO 808.6 STOPE

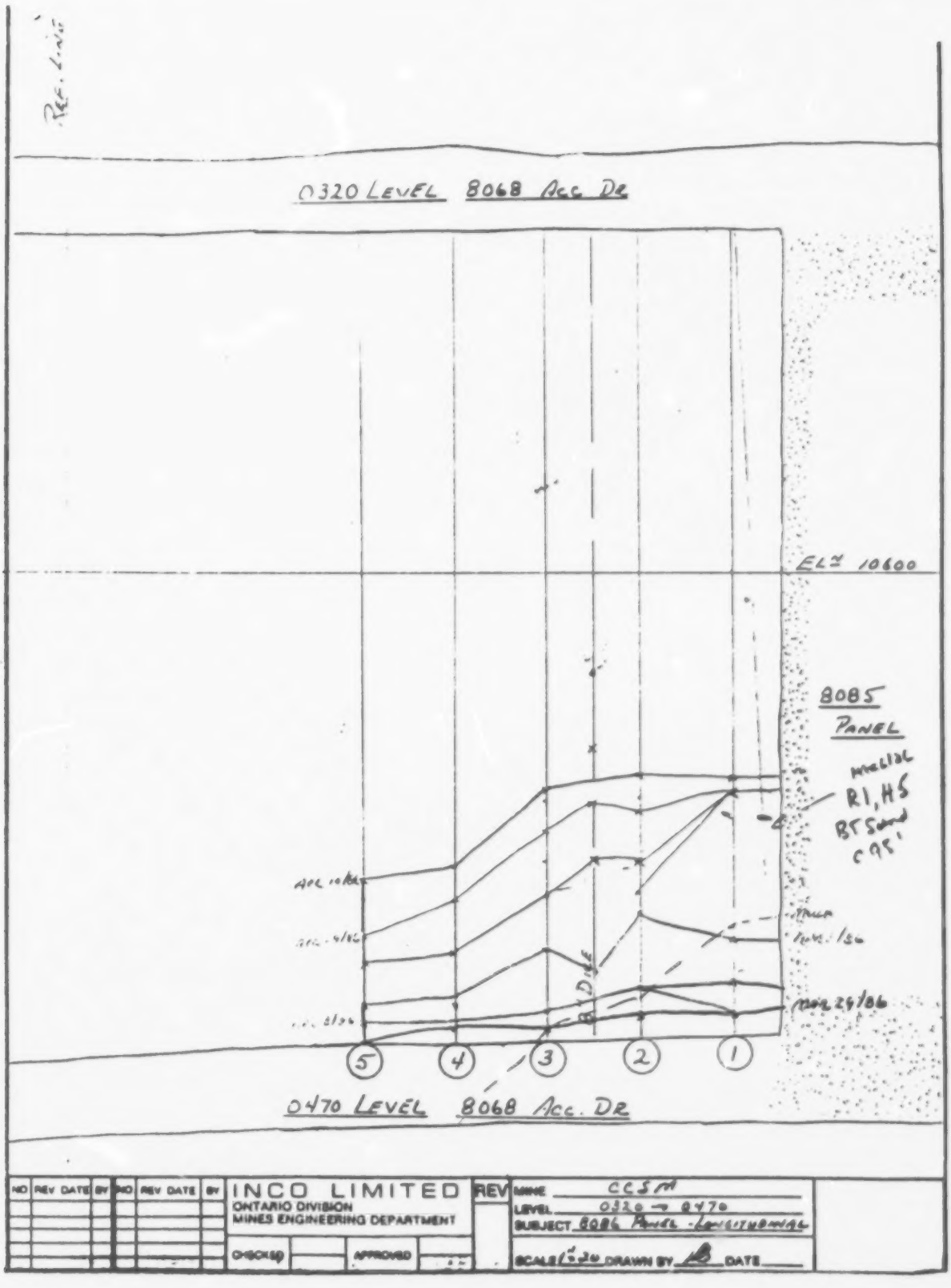
0	0	10545	REFERENCE POINT (ft)
90	90	160	STOPE LENGTH WIDTH DEPTH (ft)
0			REFERENCE ANGLE (degrees)



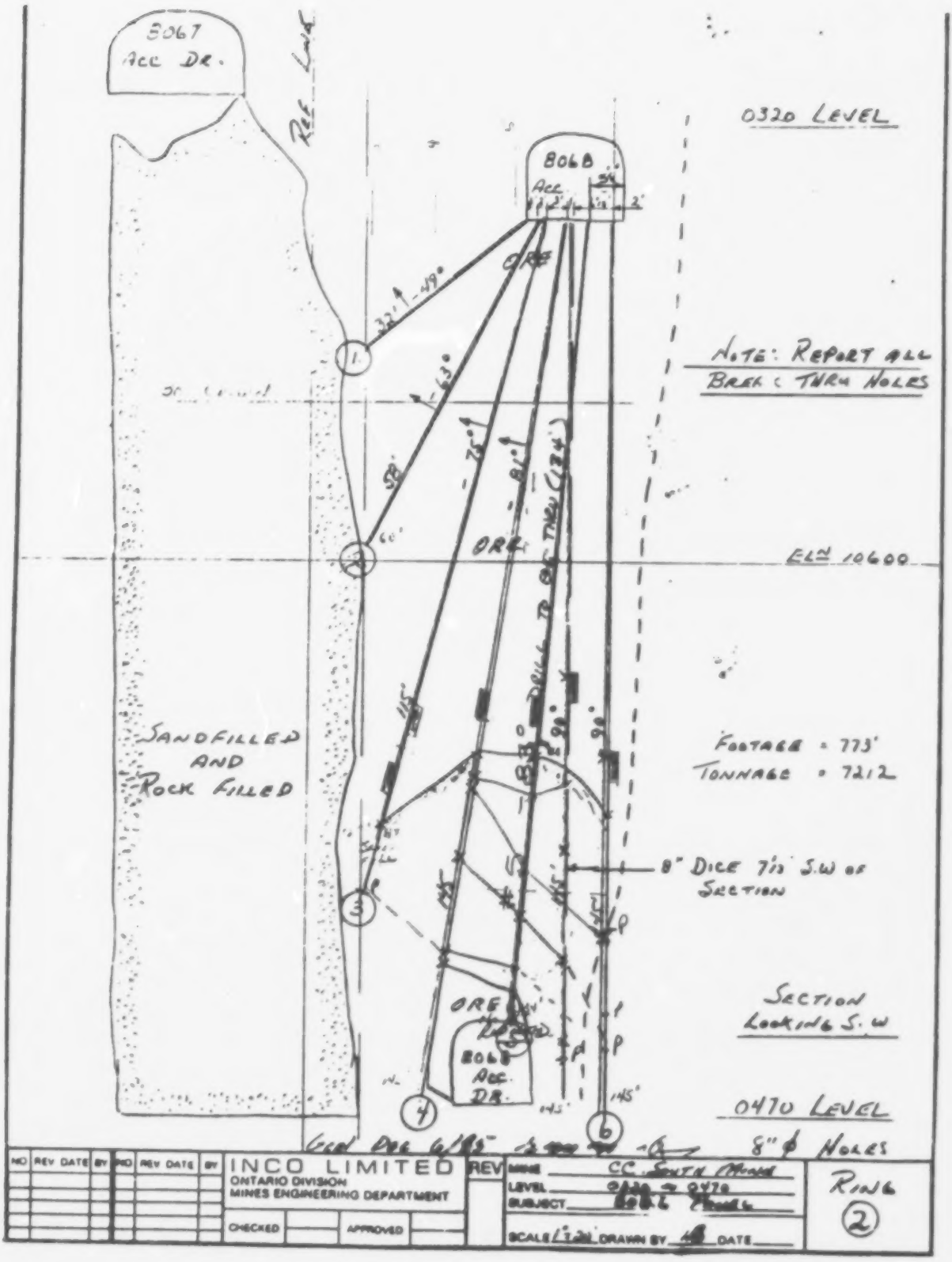
DRILLING PLAN, INCO 808.6 STOPE



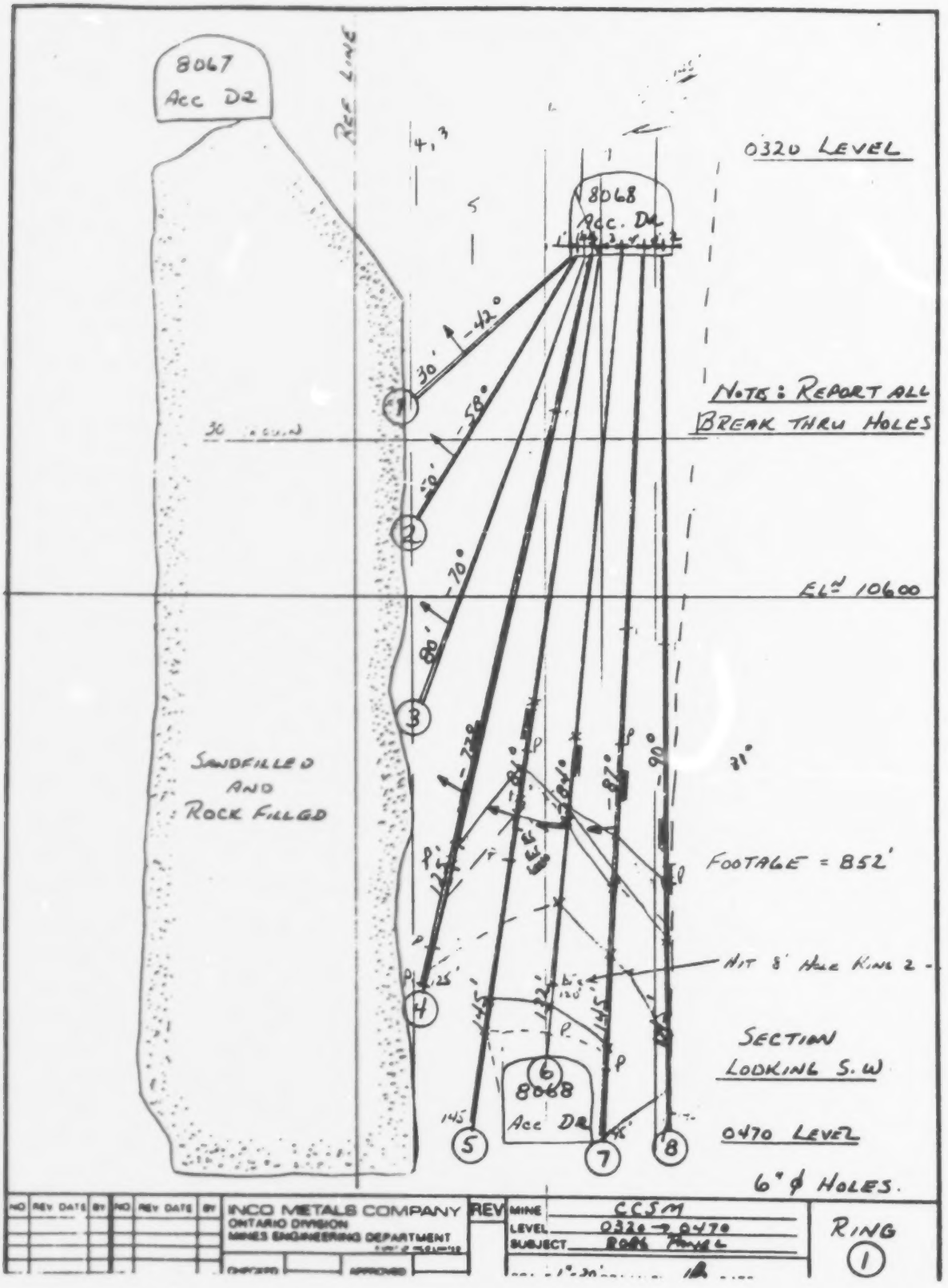
UNDERCUT PLAN, INCO 808.6 STOPE



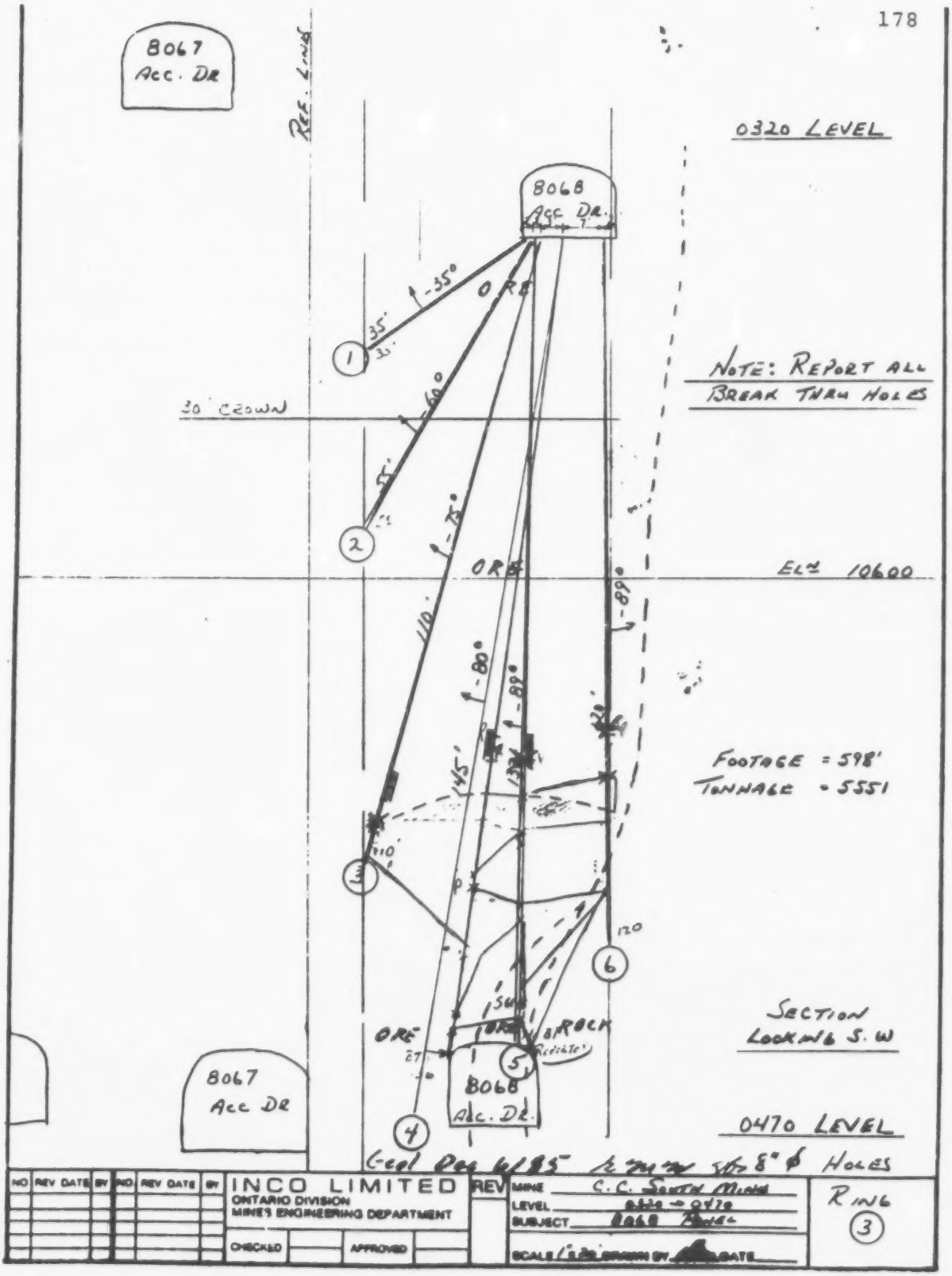
CROSS SECTION, INCO 808.6 STOPE



CROSS SECTION, INCO 808.6 STOPE



CROSS SECTION, INCO 808.6 STOPE



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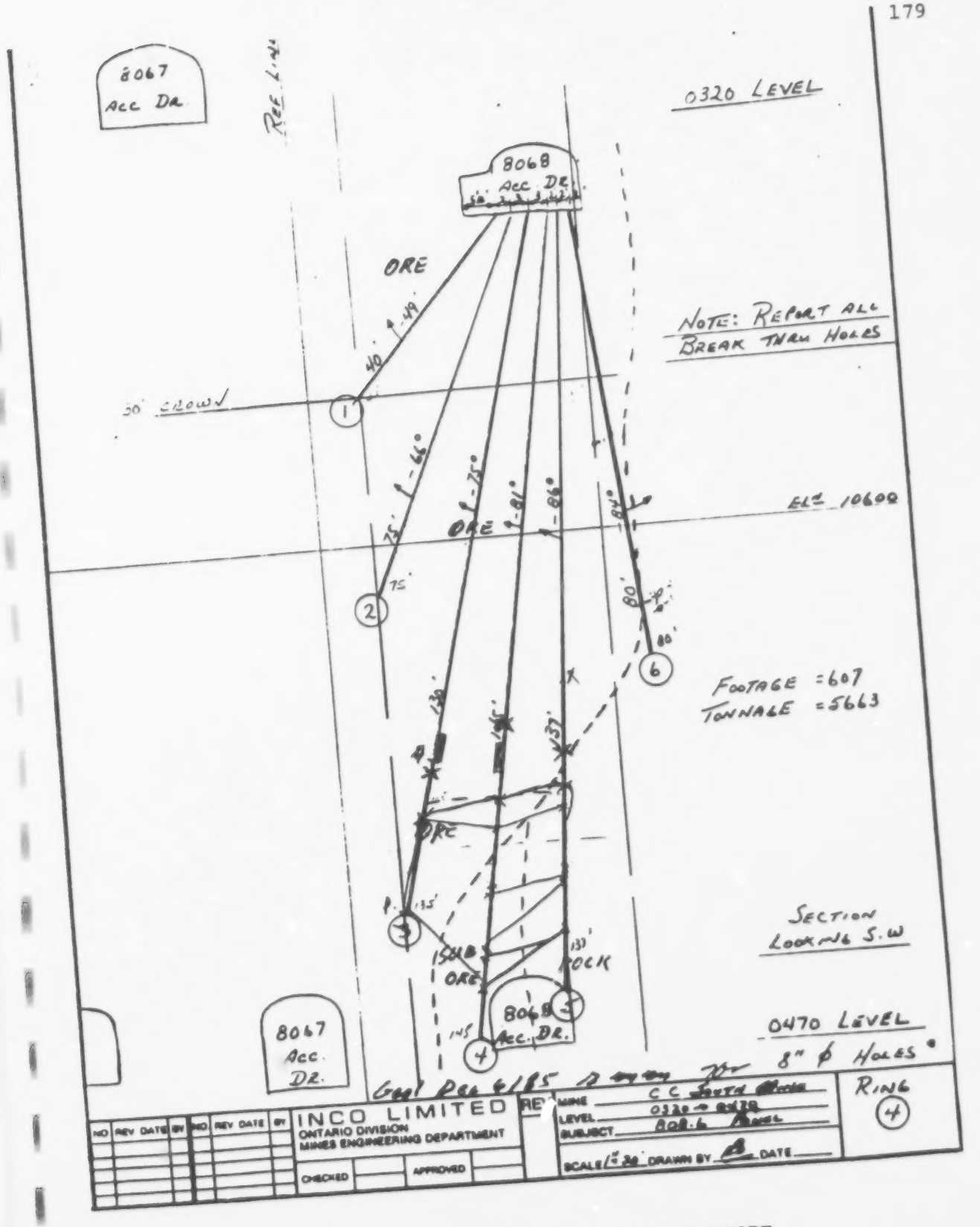
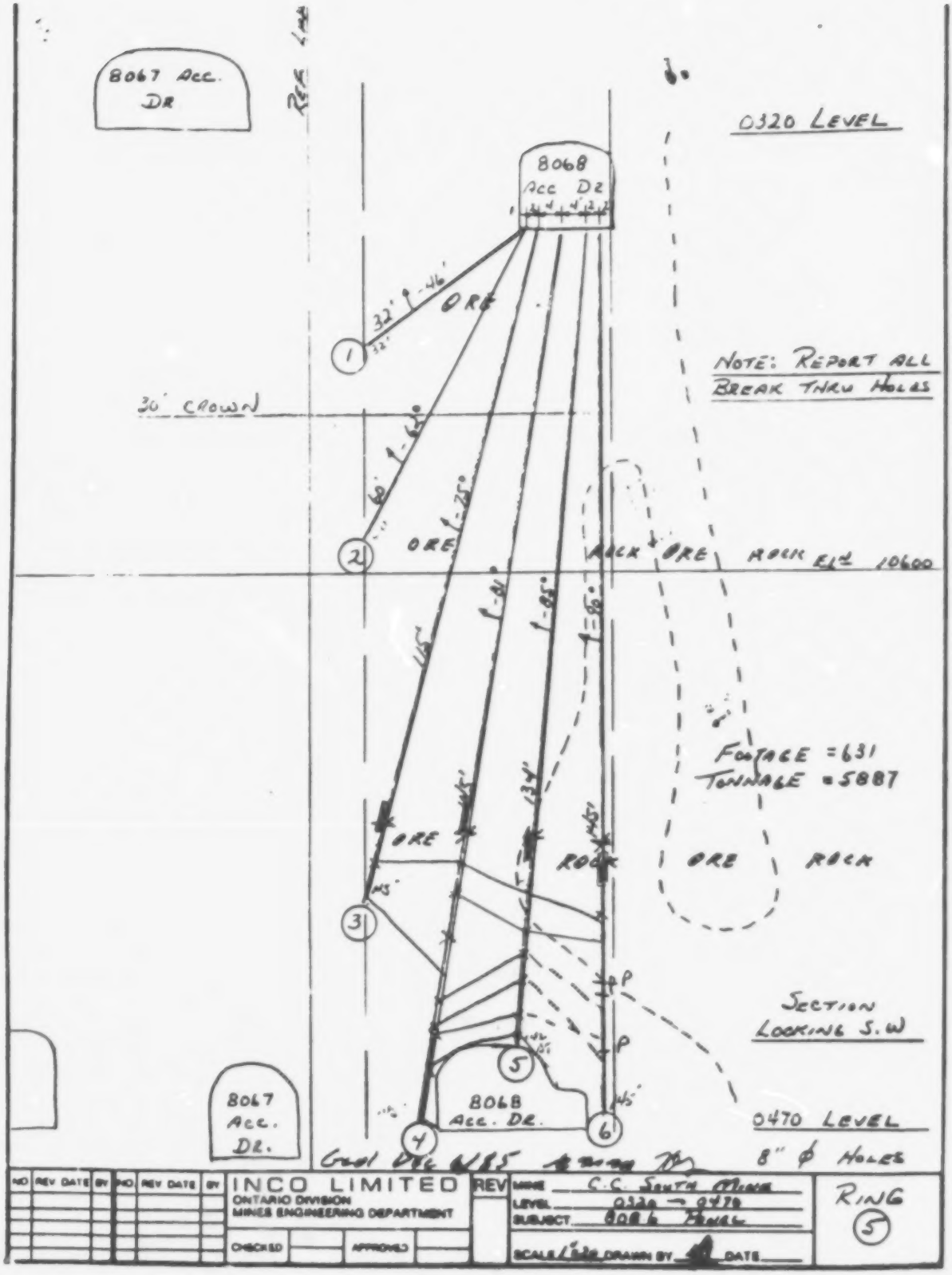


CROSS SECTION, INCO 808.6 STOPE



CROSS SECTION, INCO 808.6 STOPE

Date APR-14-86

Ring No.	Hole No.				
	2				
	3				
6' Holes	4	26	PLUGGED		1/2 ST.
	5	74	"		
	6A				
	6	79	"		
	7	61	PLUGGED		1/2 ST.
	8	64	"		1/2 ST.
Ring 2	Hole 1				
	2				
	3	90	PLUGGED		1/2 ST.
	4	55	✓✓		1/2 ST.
	5	57	✓✓		1/2 ST.
	6	89	BT.		
8" Dice		76	BT.	114'	
Ring 3	Hole 1				
	2				
	3	100	BT		1 DECK
	4	85	"	115	
	5	86	BT		
	6	81	BT		

1 stick = 12.5 kg.

Ring 4	Hole 1				
	2				
	3	100	BT		
	4	91	BT		
	5	95		130	
	6	70	PLUGGED		
Ring 5	Hole 1				
	2				
	3	100	BT		
	4	100	"		
	5	100	"		
	6	100	"		

Comments: _____

Measured By: PAUL VASSOR & Jacques

Blast _____ Holes

_____ Decks

_____ Tons Blasted

6 Holes To Unplug
1 Hole Load

Level: C320 Stope/Panel: 8086 Date: 7 FEB 10/86

Ring	Hole	Back		Mid		Bottom	Stick
	1						
	2						
	3						
6' Holes	4	Tight Air 99 BT	B	1/2 St.		6	Dmgd Liner
SA	5	83 BT	B	1/2		4	
LA	6	70 BT	B			3	
	7	94 BT	B	1/2 St.		4	
	8	102 BT	B	1/2 St.		5	
Ring 2	Hole 1						
	2						
Air Down Hole	3	103 BT	B	1/2 St.		3	Pos 10
	4	89 BT	B			1	Pos 5
	5	89 BT	B			2	Pos 5
	6	98 BT	B			3	Pos 5
8" Dice		85 BT	B			1	Pos 5
Ring 3	Hole 1						
	2						
	3	101 BT	B			3	Pos 5
	4	87 P	B			1	Pos 5
	5	92 BT	B			1	Pos 5
	6	82 P	B			2	5
		88 B.T.		95 mud			

Ring	Hole	Back		Mid		Bottom	Stick
Ring 4	Hole 1						
	2						
	3	108 B.T. ~~98P~~	B	130 mud		4	T.T 5
	4	104 BT	B			3	Pos 5
	5	101 B.T. ~~88P~~	B			4	5
	6	70P					
Ring 5	Hole 1						
	2						
	3	107 BT	B.			6	Pos 5
	4	Cone 104-106	B	1/2		5	Pos 5
	5	109 BT	B			7	Pos 5
Top of Cone	6	112	B			8	Pos 5

Comments: 109 Sticks Hanamex
3000 lbs Aquamex.
Normal 5' Load except Doughs
Deck on Rings 1 & 2. Note Set
Plugs on Rings 4 & 5 & Back + 6'

Measured By: B. Lankdon & J. Bryant
Mario & Paul.

Blast 21 Holes
23 Decks
_____ Tons Blasted

BLASTING RECORDS, INCO 808.6 STOPE

8084 Date APR 9/86

Ring	Hole	Size	Type	Deck	Delay Sticks
	1				
	2				
	3				
6 Holes	4	3½"	106 P		
	5	3"	62 P		1/2
	6	6A	91 AT		
	7		80 P		1/2
	8		112 BT		
Ring 2	1				
	2				
	3		104 P	E	4 Pcp 10
	4		93 BT	D	1 Pcs 5
	5		95 BT	B	2 Pcs 5
	6		118 P	C	3 Pcp 10
8" Dice			94 BT	A	1 Pcs 5
Ring 3	1				
	2				
	3		108P	E	6 Pcp 10
Wall 83 P	4		106 BT	E	3 Pcs 5
	5		98 BT	E	4 Pcs 5
Wall 81 P	6		96 BT	E	5 Pcs 5

Ring	Hole	Main	Hole	Deck	Stem
Ring 4	1				
	2				
	3	109 BT	B	5	Pcs 5
	4	109 BT	E	4	Pcs 5
	5	105 BT	C	3	Pcs 5
	6				
Ring 5	1				
	2				
Fill with water	3	114 P	E	8	Pcp 10
	4	110 BT	E	5	Pcs 5
Fill with water	5	115 BT	E	6	Pcs 5
	6	117 BT	E	7	Pcs 5

Fill with water

Comments: 100 STICKS REMAINING

2750 lbs

5' OF STEMMING + NORMAL 5'

LOAD EXCEPT WHERE INDICATED

Fill with water

Measured By: PAUL + MARIO

Blast 19 Holes

18 Decks

_____ Tons Blasted

Blasted APR 9/86

BLASTING RECORDS, INCO 808.6 STOPE

— 86 DATE

		Rock	Muck	Total Sticks
Ring	Hole			
	2			
	3			
6" Holes	4	60 P		
	5	90 BT		
	6	93 BT		
	7	102 BT		
	8	100 P		
Ring 2	Hole 1			
	2			
	3	104 P		
	4	84 P		
	5	96 BT	126	
	6	118 Tight		
8" Dice		93 BT	123	
Ring 3	Hole 1			
	2			
	3	108 P		
	4	120 Tight	134	
	5	100 Tight	130	
	6	96 Tight	124	

		Rock	Muck	Total Sticks
Ring 4	Hole 1			
	2			
	3	110		
	4	119	144	
	5	115	126	
	6			
Ring 5	Hole 1			
Mild Cellar Lifters	2			
	3	114 P		
	4	117		
	5	108 P		
	6	116		

Comments: _____

Measured By: Paul + Mario

Blast _____ Holes

_____ Decks

_____ Tons Blasted

BLASTING RECORDS, INCO 808.6 STOPE

Level 2085 Stope 2086 Date 7/86

Ring	Hole	Back	Block	Delay	Stems
6' Holes	1				
	2				
	3				
	4	128 P			
	5	92 BT	14		
	6	93 BT	112		
	7	103 BT			
	8	102 P			
Ring 2	Hole 1				
	2				
	3	113 P		4	10
	4	95 BT			
	5	108 BT	126	1	5
	6	118 Tight		2	8
8" Dice		103 BT Air		1	5
Ring 3	Hole 1				
	2				
	3	108 P			
	4	108 P		3	5
	5	110 BT	137	2	5
	6	107	124	3	5
Ring 4	Hole 1				
	2				
	3	128 P		5	10
	4	120 BT	146	3	5
	5	117 BT		4	5
	6				
Ring 5	Hole 1				
	2				
	3	114 P			
	4	128 BT		6	
	5	119 BT	140	5	
	6	123 P		7	5

Comments: 80 sticks Aquagel
2200 lbs Aquamon
5' of stemming + normal 5'
load except where indicated

Measured By: Paul + Mario

Blast 13 Holes
13 Decks
____ Tons Blasted

Blasted Apr 7/86

BLASTING RECORDS, INCO 808.6 STOPE

[illegible] INCA FACE 6'6" DATE APRIL 1966

		BACK		MUCK		DELAY	STICK
RING 1	HOLE 1						
	2						
	3						
6' HOLES	4	116 P	B		8	POS 4	
	5	100 [illegible]	B		1	POS 4	
	6	106 AT	B	129	5	POS 4	
	7	116 AT	B	131	6	POS 4	
	8	106 BT	B	136	7	POS 4	
RING 2	HOLE 1						
	2						
	3						
	4	106 BT	B	126	(5)	POS 5	
	5	115 BT	B	127	(4)	POS 5	
	6	131 P	B		(5)	POS 5	
8" DICE		122 AT	B	131	3	POS 5	
RING 3	HOLE 1						
	2						
	3						
	4	123 AT	B	135	1	POS 5	
	5	112 BT	B	131	2	POS 5	
	6	118 P	B		3	POS 5	

		BACK		MUCK		DELAY	STICK
RING 4	HOLE 1						
	2						
	3						
	4	99 AT	B		6	POS 5	
	5	116 BT	B	132	7	POS 5	
	6						
RING 5	HOLE 1						
	2						
	3						
	4	132 AT	B	145	7	POS 5	
	5	123 BT	B		8	DOU 5	
FILL WITH WATER	6	135 P	B		9		10

COMMENTS: 90 STICK HOLMINEX
2275 lbs
5' STEMMING + FILL HOLES WITH WATER AS INDICATED

FILL WITH WATER

MEASURED BY: PAUL & MARIO

BLAST 17 HOLES
17 DECKS
[illegible] TONS BLASTED

BLAST AREA 4/66

BLASTING RECORDS, INCO 808.6 STOPE

LEVEL: 0320 WORKPLACE 8086 DATE APR 3/86

RING	HOLE	EACH	MUCK	DELAY	STICKS
	1				
	2				
	3				
6' HOLES	4				
	5A 5	122 BT	C	8	Pos 4
	6A 6	123 BT	Z	6	Pos 4
	7	129 BT	B	7	Pos 4
	8	140 P	B	9	Pos 8
RING 2	HOLE 1				
	2				
	3	116 P			
	4	122 BT	B	5	Pos 5
	5	124 BT	B	4	Pos 5
	6	137 P	B	6	Pos 10
8" DICE		136 BT	d	3	Pos 5
RING 3	HOLE 1				
	2				
	3				
	4	131 BT	B	1	Pos 5
	5	132 BT	B	1	Pos 5
	6				

RING 4	HOLE	BACK	MUCK	DELAY	STICKS
	1				
	2				
	3	130 P	B		Pos 4
	4	133 BT	B	2	Pos 5
	5	129 BT	B	3	Pos 5
	6				
FILL WITH WATER RING 5	HOLE 1				
	2				
	3				
	4	134 BT	B	3	Pos 5
	5	127 BT	B	4	Pos 5
	6	125 P	B		

*FILL WITH WATER

COMMENTS: 75 STICKS AQUAMEX
2065 lbs
R246 BT 16 HOLES @ 5' - 5 STICK
LOAD UNLESS INDICATED
5' OF STEMMING

MEASURED BY: PAUL

BLAST 16 HOLES
1 DECKS
_____ TONS BLASTED

BLASTED APR 3/86

BLASTING RECORDS, INCO 808.6 STOPE

LEVEL : 3320 INCH FACE 6086 DATE MAR 31/86

RING	HOLE	BACK	MUCK	DELAY	STICKS
RING 1	1				
	2				
	3				
6" HOLES	4				
	5A 5	126 [illegible]	B 143	7	P.S 5
	6A 6	[illegible]	B	6	P.S 5
	7	133 P	B	7	P.S 5
	8				
RING 2	1				
	2				
	3				
	4	124 BT	B	4	P.S 5
	5	128 BT	B	5	P.S 5
	6	142 P	B	6	P.S 5
8" DICE		139 P	B	3	P.S 5
RING 3	1				
	2				
	3				
	4	132 BT	B	1	P.S 5
	5	129 BT	B	1	P.S 5
	6				
RING 4	1				
	2				
	3				
	4	137 BT	B	2	P.S 5
	5	126 BT	B	3	P.S 5
	6				
RING 5	1				
	2				
	3				
	4	139 BT	B	3	P.S 5
	5	132 BT	B	4	P.S 5
	6	145 P	B	5	P.S 5

COMMENTS: 70 STICKS AQUANEX
1925 lbs
PLUG BT HOLES @ 5' - 5 STICK
LOAD + 5' OF STEMMING.
COLLARS OK

MEASURED BY: PAUL

BLAST 14 HOLES
14 DECKS
____ TONS BLASTED

BLASTED APRIL 2/86

LEVEL 0320 WORKPLACE 8086 DATE Mar 28/86

RING	HOLE	BACK	MUCK	DELAY	STICK
	1	29P			
	2	47P			
	3	72P			
6" HOLES	4	118P			
	5A	84P			
	5	141P			
	6A	134P			
	6	137P -X-			
	7	133P			
	8	142P			
RING 2	HOLE 1	31P			
	2	59P			
	3	115P			
	4	136P B		3	P.P 5'
	5	136 B		6	P.P 5'
	6	142P X			
8" DICE		146P B		3	P.P 5'
RING 3	HOLE 1	35P			
	2	53P			
	3	110P			
	4	136 BT B		1	P.P. 5'
	5	133 BT B		2	P.P 5'
	6	121P			

RING 4	HOLE	BACK	MUCK	DELAY	STICK
	1	37P			
	2	75P			
	3	131P			
	4	146P B		4	P.P 5'
	5	136 BT B		3	P.P 5'
	6	80P			
RING 5	HOLE 1	30P			
	2	60P			
	3	115P			
	4	145P B		5	P.P 5'
	5	142 BT B.		4	P.P 5'
	6	145P X			P.P 5'

COMMENTS: PLUG @ 5' OR @ PUL IN HOLE - 5 STICK LOAD + 5' OF STEMMING.

NOTE: MUCK OUT 10' OF SAND ON 470 LEVEL

MEASURED BY: G GLENN.

BLAST 9 HOLES
9 DECKS
____ TONS BLASTED

BLASTED MAR 29/86

BLASTING RECORDS, INCO 808.6 STOPE

PROGRAM VCRM OUTPUT

WRITTEN FOR THE DESIGN OF THE BLAST IN AN UNDERGROUND STOPE USING THE VERTICAL CRATER RETREAT METHOD.

INCO STOPE 8086 1ST LIFT

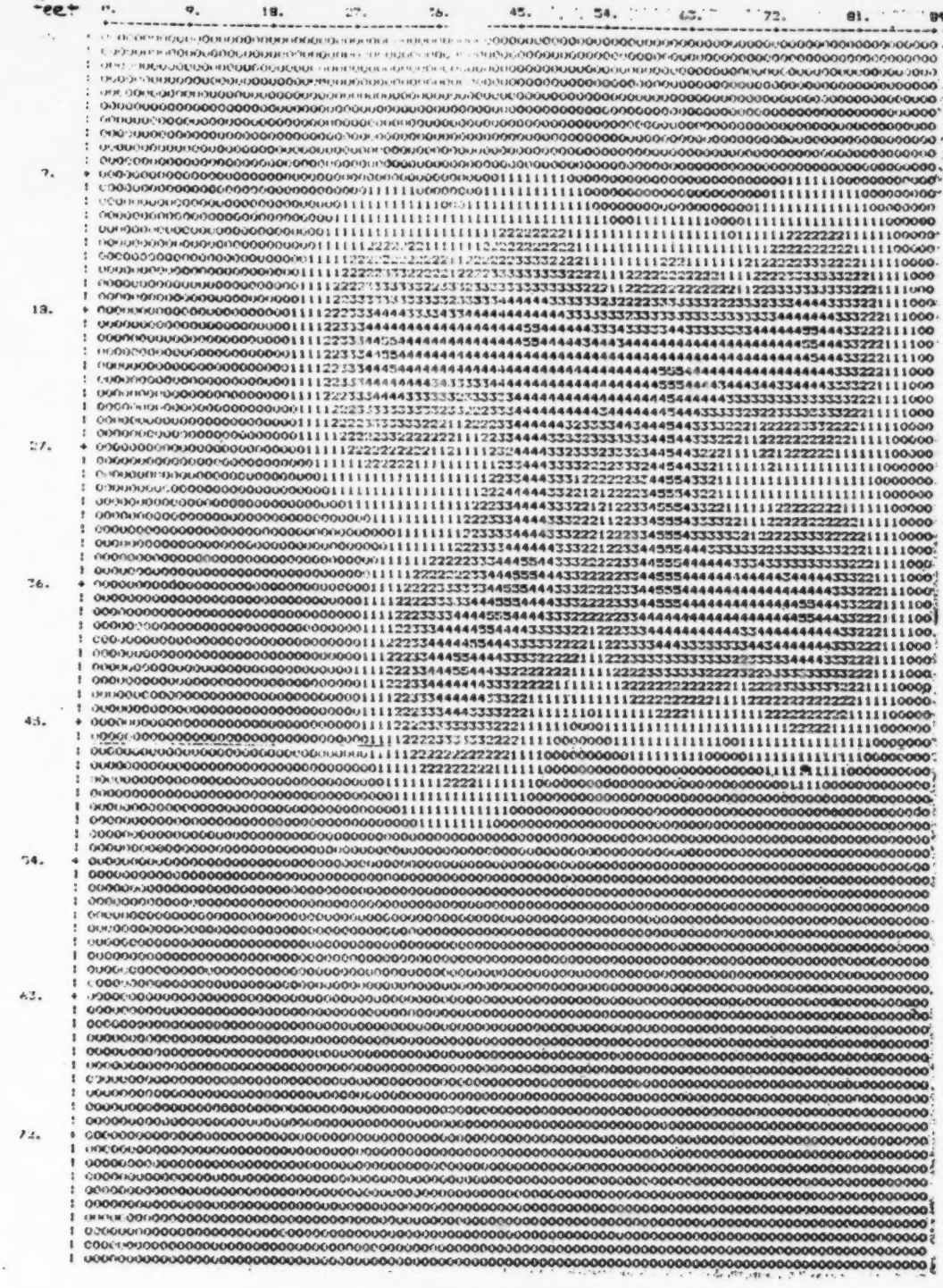
EXPLOSIVE USED: AQUA
DENSITY: 0.0400 LBS/CU. INCH
DIAMETER: 8.0000 INCHES

MODIFIED INITIATION SEQUENCE

HOLE NUMBER	DELAY PERIOD
1	2
2	2
3	1
4	2
5	3
6	2
7	4
8	4
9	3

WEIGHT OF CHARGES IN THE BLAST

HOLE NUMBER	CHARGE WEIGHT (lbs)
1	88
2	88
3	88
4	88
5	88
6	88
7	88
8	88
9	88



PLAN VIEW OF THE BLAST

ELEVATIONS REPRESENTED BY THE NUMBERS OF THE PRINTOUT

NUMBER 0	131 FT	NUMBER 3	126 FT
NUMBER 1	129.3 FT	NUMBER 4	124.3 FT
NUMBER 2	127.6 FT	NUMBER 5	122.6 FT

INCO 808.6 Stope, 1ST LIFT OUTPUT

SUMMARY

TOTAL WEIGHT OF EXPLOSIVE: 790 LBS

ESTIMATED TONNAGE BROKEN: 1034 TONS

DELAY NUMBER	QUANTITY
1	1
2	4
3	2
4	2

INSTRUCTIONS FOR LOADING

HOLE NUMBER	CHARGE LOCATION DISTANCE TO CENTRE OF CHARGE	CHARGE WEIGHT (lbs)	DELAY NUMBER
1	126	88	2
2	125	88	2
3	126	88	1
4	124	88	2
5	126	88	3
6	125	88	2
7	126	88	4
8	125	88	4
9	124	88	3

PROGRAM VCRM

WRITTEN FOR THE DESIGN OF THE BLAST IN AN UNDERGROUND STOPE USING THE VERTICAL CRATER RETREAT METHOD.

INCO STOPE 8086 2ND LIFT

EXPLOSIVE USED: AQUA
DENSITY: 0.0400 LBS/CU. INCH
DIAMETER: 8.0000 INCHES

MODIFIED INITIATION SEQUENCE

HOLE NUMBER	DELAY PERIOD
1	5
2	4
3	5
4	3
5	2
6	4
7	1
8	2
9	2
10	3
11	4
12	4
13	5
14	3

WEIGHT OF CHARGES IN THE BLAST

HOLE NUMBER	CHARGE WEIGHT (lbs)
1	88
2	88
3	88
4	88
5	88
6	88
7	88
8	88
9	88
10	88
11	88
12	88
13	88
14	88

PLAN VIEW OF THE BLAST

ELEVATIONS REPRESENTED BY THE NUMBERS OF THE PRINTOUT

NUMBER 0	125 FT	NUMBER 3	120 FT
NUMBER 1	123.3 FT	NUMBER 4	118.3 FT
NUMBER 2	121.6 FT	NUMBER 5	116.6 FT

INCO 808.6 STOPE, 2ND LIFT OUTPUT

SUMMARY

TOTAL WEIGHT OF EXPLOSIVE: 1228 LBS

ESTIMATED TONNAGE BROKEN: 1679 TONS

DELAY NUMBER	QUANTITY
1	1
2	3
3	3
4	4
5	3

INSTRUCTIONS FOR LOADING

HOLE NUMBER	CHARGE LOCATION DISTANCE TO CENTRE OF CHARGE	CHARGE WEIGHT (lbs)	DELAY NUMBER
1	120	88	5
2	119	88	4
3	119	88	5
4	120	88	3
5	119	88	2
6	118	88	4
7	120	88	1
8	118	88	2
9	120	88	2
10	119	88	3
11	120	88	4
12	119	88	4
13	118	88	5
14	118	88	3

PROGRAM VCRM

WRITTEN FOR THE DESIGN OF THE BLAST IN AN UNDERGROUND STOPE USING THE VERTICAL CRATER RETREAT METHOD.

INCO STOPE 8086 3RD LIFT

EXPLOSIVE USED: AQUA
DENSITY: 0.0400 LBS/CU. INCH
DIAMETER: 8.0000 INCHES

MODIFIED INITIATION SEQUENCE

HOLE NUMBER	DELAY PERIOD
1	4
2	5
3	4
4	5
5	2
6	3
7	2
8	3
9	1
10	2
11	3
12	5
13	4
14	3

WEIGHT OF CHARGES IN THE BLAST

HOLE NUMBER	CHARGE WEIGHT (lbs)
1	88
2	88
3	88
4	88
5	88
6	88
7	88
8	88
9	88
10	88
11	88
12	88
13	88
14	88

PLAN VIEW OF THE BLAST

ELEVATIONS REPRESENTED BY THE NUMBERS OF THE PRINTOUT

NUMBER 0	119 FT	NUMBER 3	114 FT
NUMBER 1	117.3 FT	NUMBER 4	112.3 FT
NUMBER 2	115.6 FT	NUMBER 5	110.6 FT

INCO 808.6 STOPE, 3RD LIFT OUTPUT

SUMMARY

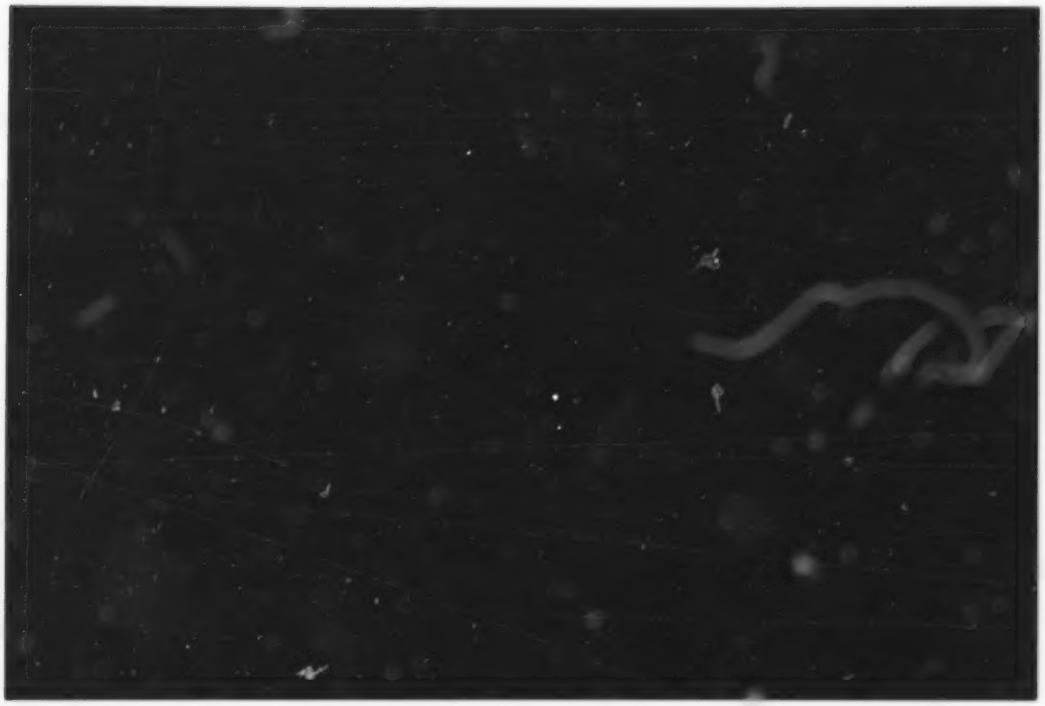
TOTAL WEIGHT OF EXPLOSIVE: 1228 LBS

ESTIMATED TONNAGE BROKEN: 1697 TONS

DELAY NUMBER	QUANTITY
1	1
2	4
3	3
4	3
5	3

INSTRUCTIONS FOR LOADING

HOLE NUMBER	CHARGE LOCATION DISTANCE TO CENTRE OF CHARGE	CHARGE WEIGHT (lbs)	DELAY NUMBER
1	114	88	4
2	113	88	5
3	113	88	4
4	112	88	5
5	114	88	2
6	113	88	3
7	112	88	2
8	114	88	3
9	112	88	1
10	114	88	2
11	113	88	3
12	114	88	5
13	113	88	4
14	112	88	2



MUCKPILE PHOTOGRAPH 808.6 STOPE

DATA AND RESULTS FOR FALCONBRIDGE 20-134 DROP RAISE

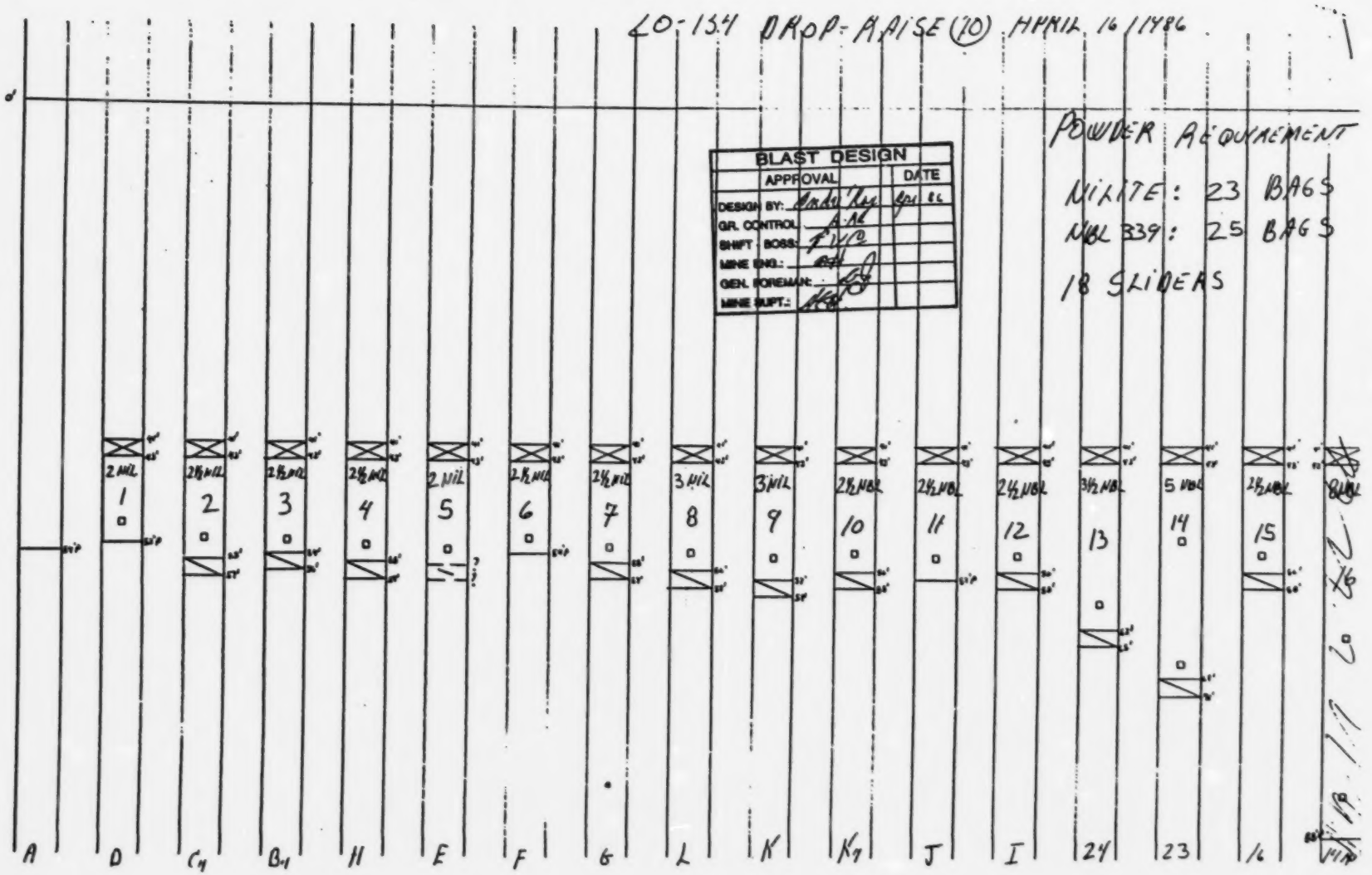
HOLE COORDINATES

HOLE #	ROW	COLUMN	x(ft)	y(ft)	z(ft)
1	4	2	1327	106	10932
			1326	17	11080
2	5	3	1329	107	10932
			1327	15	11080
3	3	3	1329	103	10932
			1327	15	11080
4	5	32	1328	108	10932
			1329	18	11080
5	4	1	1325	105	10932
			1331	18	11080
6	3	2	1328	102	10932
			1330	18	11080
7	4	4	1331	105	10932
			1331	19	11080
8	6	1	1324	109	10932
			1328	19	11080
9	6	4	1332	109	10932
			1335	17	11080
10	6	5	1335	109	10932
			1340	20	11080
11	2	4	1332	109	10932
			1333	15	11080
12	2	1	1324	99	10932
			1331	14	11080
13	4	5	1337	105	10932
			1340	17	11080
14	2	5	1336	99	10932
			1333	3	11080
15	1	1	1325	95	10932
			1327	8	11080

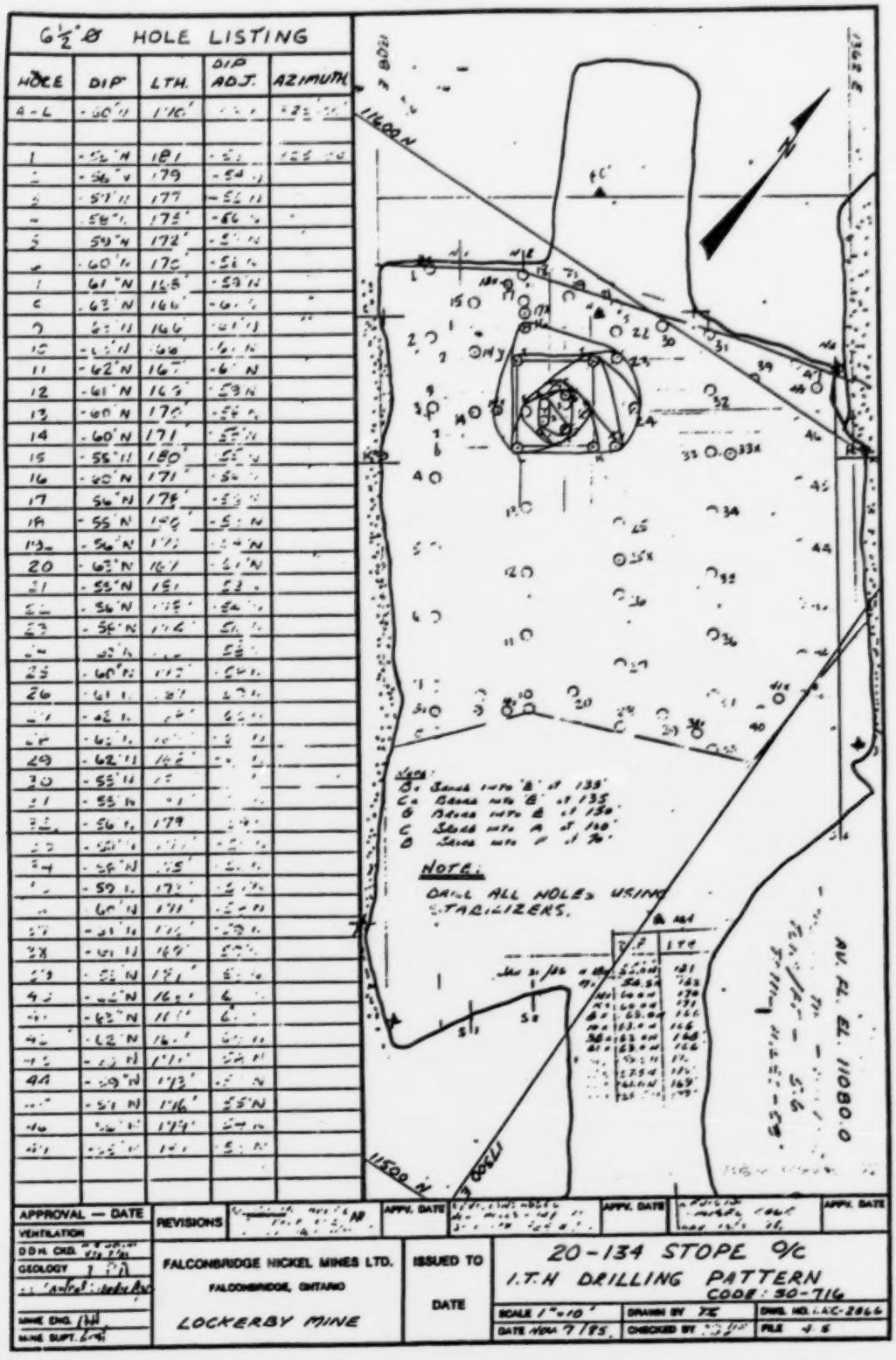
REFERENCE DATA

TEST STOPE FROM FALCONBRIDGE 20 - 134 DR RAISE

1308	0	10932	REFERENCE POINT (ft)
55	140	148	STOPE LENGTH WIDTH DEPTH (ft)
00			REFERENCE ANGLE (degrees)



LOADING INSTRUCTIONS, 20-134 STOPE



6½" Ø HOLE LISTING

HOLE	DIP	LTH.	DIP ADJ.	AZIMUTH
A-L	-60°N	176'		
1	-52°N	181'		
2	-56°N	179'		
3	-57°N	177'		
4	-56°N	175'		
5	-59°N	172'		
6	-60°N	170'		
7	-61°N	168'		
8	-63°N	166'		
9	-61°N	166'		
10	-61°N	168'		
11	-62°N	167'		
12	-61°N	169'		
13	-60°N	170'		
14	-60°N	171'		
15	-58°N	180'		
16	-60°N	171'		
17	-56°N	178'		
18	-55°N	180'		
19	-56°N	177'		
20	-62°N	167'		
21	-55°N	181'		
22	-56°N	179'		
23	-56°N	177'		
24				
25	-60°N	173'		
26	-61°N	171'		
27	-62°N	169'		
28	-63°N	167'		
29	-62°N	169'		
30	-58°N	175'		
31	-58°N	175'		
32	-56°N	179'		
33	-58°N	175'		
34	-59°N	173'		
35	-60°N	171'		
36	-61°N	169'		
37	-58°N	175'		
38	-62°N	169'		
39	-62°N	169'		
40	-62°N	169'		
41	-59°N	173'		
42	-58°N	176'		
43	-56°N	179'		
44	-58°N	176'		

NOTE:
DRILL ALL HOLES USING STABILIZERS.

APPROVAL — DATE	REVISIONS	APPV. DATE	APPV. DATE	APPV. DATE
VENTILATION				
DDH. CKD.				
GEOLOGY				
MINE ENG.				
MINE SUPT.				

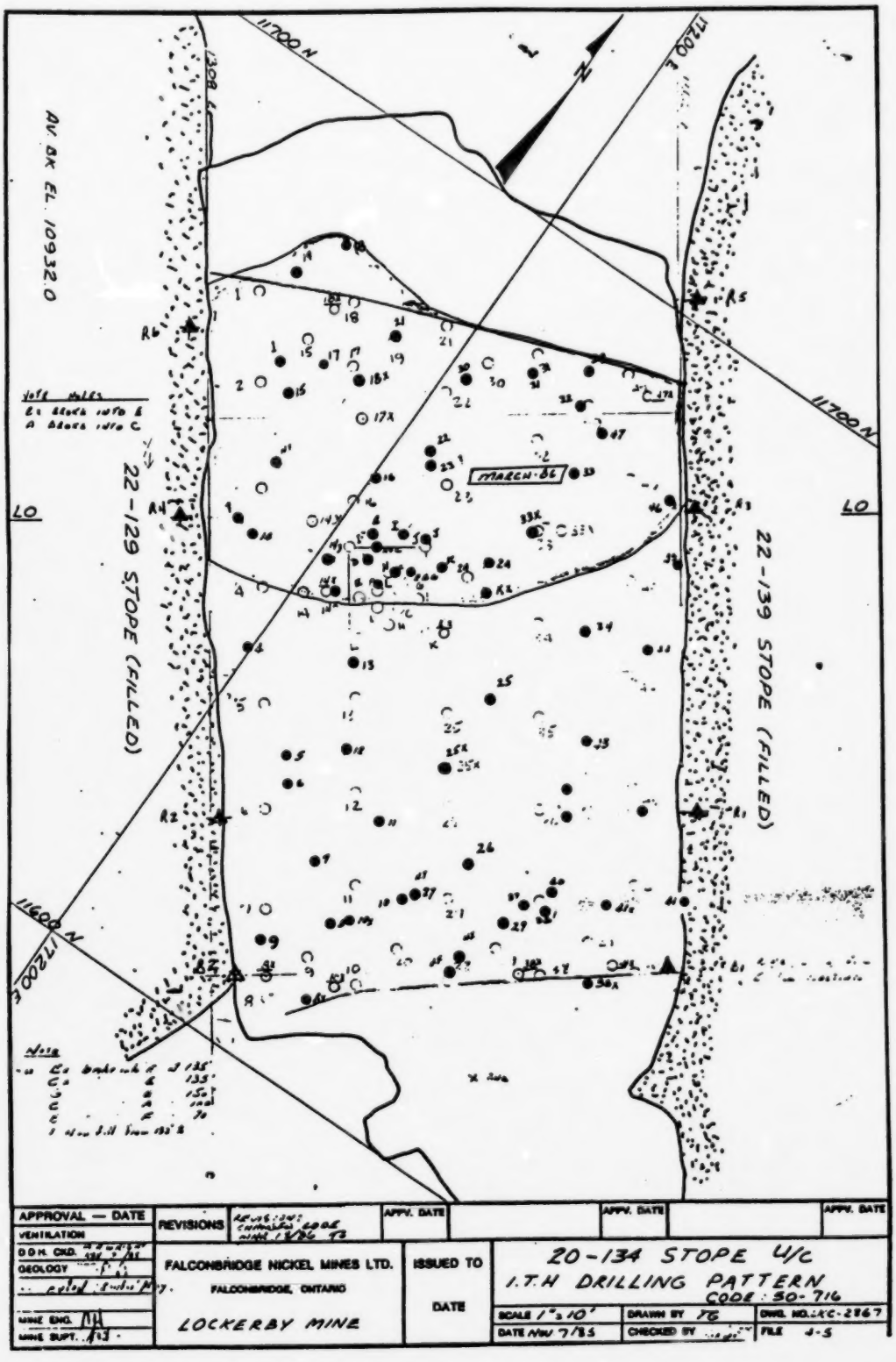
FALCONBRIDGE NICKEL MINES LTD.
FALCONBRIDGE, ONTARIO
LOCKERBY MINE

ISSUED TO
DATE

20-134 STOPE O/C
I.T.H DRILLING PATTERN
CODE: 30-716

SCALE 1"=10'	DRAWN BY TE	DWG. NO. LKC-2664
DATE NOV 7/85	CHECKED BY	FILE 4.6

DRILLING PLAN, 20-134 STOPE OVERCUT



DRILLING PLAN, 20-134 STOPE UNDERCUT

PROGRAM VCRM

WRITTEN FOR THE DESIGN OF THE BLAST IN AN UNDERGROUND STOPE USING THE VERTICAL CRATER RETREAT METHOD.

TEST STOPE FROM FALCONBRIDGE 20-134 DR RAISE

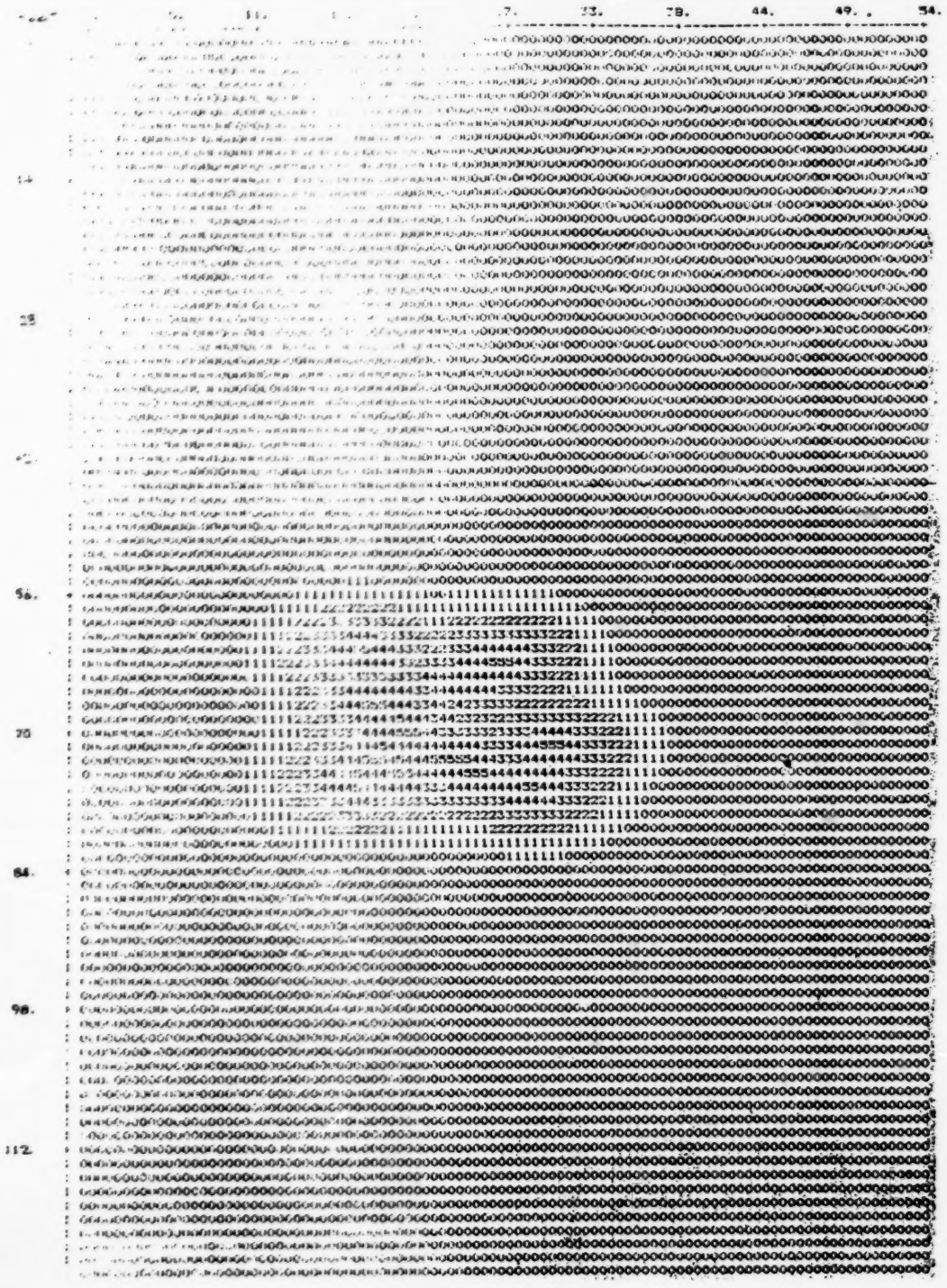
EXPLOSIVE USED: NILITE
DENSITY: 0.0310 LBS/CU. INCH
DIAMETER: 6.5000 INCHES

MODIFIED INITIATION SEQUENCE

HOLE NUMBER	DELAY PERIOD
1	1
2	1
3	1
4	1
5	1
6	2
7	3
8	2
9	4
10	2
11	2
12	5
13	4
14	4
15	4

WEIGHT OF CHARGES IN THE BLAST

HOLE NUMBER	CHARGE WEIGHT (lbs)
1	36
2	36
3	36
4	36
5	36
6	36
7	36
8	36
9	36
10	36
11	36
12	36
13	36
14	36
15	36



PLAN VIEW OF THE BLAST

ELEVATIONS REPRESENTED BY THE NUMBERS OF THE PRINTOUT

NUMBER 0	66 FT	NUMBER 3	63.2 FT
NUMBER 1	65.1 FT	NUMBER 4	62.2 FT
NUMBER 2	64.1 FT	NUMBER 5	61.3 FT

FALCONBRIDGE 20-134 DROP RAISE OUTPUT

SUMMARY

TOTAL WEIGHT OF EXPLOSIVE: 547 LBS

ESTIMATED TONNAGE BROKEN: 168 TONS

DELAY NUMBER	QUANTITY
1	6
2	4
3	1
4	3
5	1

INSTRUCTIONS FOR LOADING

HOLE NUMBER	CHARGE LOCATION	CHARGE WEIGHT	DELAY NUMBER
1	61	36	1
2	62	36	1
3	61	36	1
4	62	36	1
5	61	36	1
6	60	36	1
7	61	36	2
8	62	36	3
9	62	36	2
10	61	36	4
11	62	36	2
12	61	36	2
13	61	36	5
14	63	36	4
15	61	36	4

APPENDIX C

KUZ-RAM FRAGMENTATION MODEL

THE KUZ-RAM MODEL

This describes briefly the development of the model.

Kuznetsov's Equation

The equation given is

$$\bar{x} = A \left(\frac{V_o}{Q}\right)^{0.8} Q^{1/6} \qquad \text{Eq(1)}$$

where: $\bar{x}$ = mean fragment size, cm.

A = rock factor = 7 for medium rocks.
10 for hard, highly fissured rocks.
13 for hard, weakly fissured rocks. To date we have found the lower limit to be 8, even in quite weak rock types, and have yet to encounter rock requiring a factor in excess of 12.

V_o = rock volume (cubic metres) broken per blasthole, taken as Burden x Spacing x Bench Height.

Q = mass (Kg) of TNT which is equivalent in energy to that of the explosive charge in each blasthole.

We normally exclude the explosive in the sub-drill section, as this seldom contributes significantly to fragmentation in the column area.

If Q_e = mass per blasthole of explosive being used, and

E = Relative Weight Strength of this explosive, (ANFO = 100), then as the Relative Weight Strength of TNT = 115.

$$Qe \times E = Q \times 115$$

$$Q = Qe \frac{E}{115}$$

Eq(1) then becomes:

$$\bar{x} = A \left(\frac{V_o}{Qe}\right)^{0.8} Qe^{1/6} \left(\frac{E}{115}\right)^{1/6} \left(\frac{E}{115}\right)^{-0.8}$$

which becomes:

$$\bar{x} = A \left(\frac{V_o}{Qe}\right)^{0.8} Qe^{1/6} \left(\frac{E}{115}\right)^{-19/30} \qquad \text{Eq(2)}$$

The expression $\frac{V_o}{Qe}$ is the inverse of the specific charge or powder factor, K, kg/cubic metre.

Thus in the form most useful to explosives engineers, Eq(2) becomes:

$$\bar{x} = A(K)^{-0.8} Qe^{1/6} \left(\frac{115}{E}\right)^{19/30} \qquad \text{Eq(3)}$$

This is readily inverted to obtain the necessary powder factor if a certain mean fragmentation is required.

Rosin-Rammler Equation

$$R = \bar{e}^{\left(\frac{x}{x_c}\right)^n}$$

Eq(4)

Eq (3) gives $\bar{x}$, ie. value of $\bar{x}$ when R = 0.5

$$\therefore \quad 0.5 = \bar{e}^{\left(\frac{\bar{x}}{x_c}\right)^n}$$

$$\therefore \quad x_c = \frac{x}{(0.693)^{1/n}}$$

Eq(5)

"n" determines the shape of the curve and commonly varies between 0.8 and 2.2. High values indicate uniform sizing, while low values result in higher proportions of both fines and oversize.
X_c is the characteristic size of the material, constant for a given situation.

Effect of Blasting Parameters "n"

It would normally be desirable to have uniform fragmentation, avoiding both fines and oversize, so high values of "n" are preferred. The algorithm used gives blasting parameters the following effect on values of "n".

Parameter	"n" increases as Parameter:
Burden/Hole Diameter	decreases
Drilling Accuracy	increases
Charge Length/Bench Height	increases
Spacing/Burden	increases

For staggered rather than rectangular patterns, "n" increases.

The present form of algorithm used is:

$$n = (2.2 - 14\ B/d)(1 - W/B)(1 + (A - 1)/2)L/H \qquad \text{Eq(6)}$$

where
- B = burden (m)
- d = hole diameter (mm)
- W = standard deviation of drilling accuracy (m)
- A = spacing/burden ratio
- L = charge length above grade level (m)
- H = bench height (m)

If a staggered drilling pattern is employed, "n" as detailed above is increased by 10%.

Limitations on Kuz-Ram Model

A simple model such as this requires caution in use and the following should be understood.

(a) The S/B ratio applies to the drilling, not the timing layout and should not exceed 2.

(b) Initiation and timing must be arranged so as to reasonably enhance fragmentation and avoid misfires or cut-offs.

(c) The explosive should yield energy close to its calculated Relative Weight Strength.

(d) The jointing and homogeneity of the ground require careful assessment, as fragmentation is often built into the rock structure, especially when loose jointing is more closely spaced than the drilling pattern.

APPENDIX D

VIBRATION MONITORING EQUIPMENT SPECIFICATIONS

EQUIPMENT SPECIFICATIONS

MREL DIGITAL RECORDER

INPUT CHANNELS: 3

SAMPLING RATE: 1000 μs

FREQUENCY RESPONSE: 1HZ - 500 HZ

MAX. INPUT VOLTAGE: 10 V

TRIGGER LEVEL: 0.625 V

RESOLUTION: 8% OF FULL SCALE

RACAL FM TAPE RECORDER

INPUT CHANNELS: 7

SAMPLING RATE: CONTINUOUS

FREQUENCY RESPONSE: 0 - 5000 Hz

MAX. INPUT VOLTAGE: 20 V

MAX. RECORD DURATION: 1 HOUR

TRIGGER LEVEL: NONE